Corrosion

There's more to CORROSION than meets the eye

Sometimes VISIBLE... Often HIDDEN... Corrosion Strikes in Every Plant

This year, American Industry will pay more than $6,000,000,000 for losses created by corrosion... *yet much of this corrosion may never be discovered* until it's too late to protect—and time to pay!

Corrosion is readily detected when it appears as rust layers or failing paint on exposed surfaces. But, by far, the major costs of corrosion come from hidden areas—where only minute inspections and constant care can prevent costly failures.

YOU LOSE IN A "WAITING GAME"

Don't wait for rust or other visible signs to appear. Visible or hidden, corrosion will destroy costly equipment... halt production... cause unnecessary maintenance shutdowns... and contaminate valuable products. Thus, corrosion dips deep into your profits as it creates needless losses totaling thousands of dollars.

YOU CAN PREVENT NEEDLESS WASTE

Check your plant for corrosion's presence. Double-check areas that are vulnerable to *hidden corrosion*. If you would like help, an AMERCOAT Field Engineer will gladly assist you in making a thorough analysis. There is no obligation.

What is AMERCOAT?

AMERCOAT is a method of corrosion control. Not just a single product, but a complete LINE of coatings, individually formulated to solve or control specific industrial corrosion problems.

FOLLOW THE LINE OF *most* RESISTANCE... PROTECT WITH *Amercoat!*

AMERCOAT CORPORATION

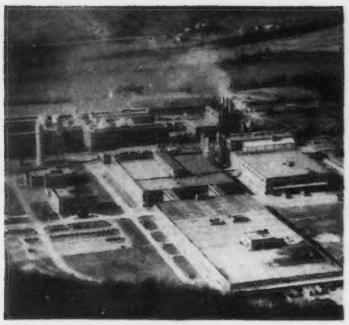
4809 FIRESTONE BLVD., SOUTH GATE, CALIFORNIA

CHICAGO, ILL. NEWARK, N. J. JACKSONVILLE, FLA. DALLAS, TEX.

No. 111-A gate valve for 150 pounds made in a wide range of analyses to and regularly stocked in popular alloys.

Lasts longer in corrosive service

This bolted bonnet type gate valve, made to specification, provides the three basic advantages of all ALOYCO valves . . . (1) special engineering for severe corrosive service through (2) extensive metallurgical research and production of high alloy valves exclusively.



Celanese values valves for long wear, too

The same insistence on quality that makes Celanese* acetate yarns and fibers outstanding marks Celanese Corporation's choice of valves.

That's why Celanese called on the *Aloyco Corrosion Clinic* to recommend a valve for handling acetic anhydride and acetic acid used in making cellulose acetate flake. After thorough analysis of these corrosives, the Clinic advised ALOYCO 18-8SMo No. 111-A high alloy gate valves.

Like Celanese, thousands of leading firms in the process industries have found that the correct ALOYCO valve lasts longer (lower valve cost) and reduces valve maintenance and downtime for valve repair or replacement.

Why? Because the *Aloyco Corrosion Engineers specialize* in corrosion-resistant valves for solving problems of severe service and product contamination.

For effective "diagnosis" and "treatment" of such problems, big or small, consult the *Aloyco Corrosion Clinic* for expert advice and engineering service.

*Reg. U. S. Pat. Off.

ALLOY STEEL PRODUCTS CO., INC.
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Longer Lasting

ALOYCO VALVES

1st in Corrosive Service

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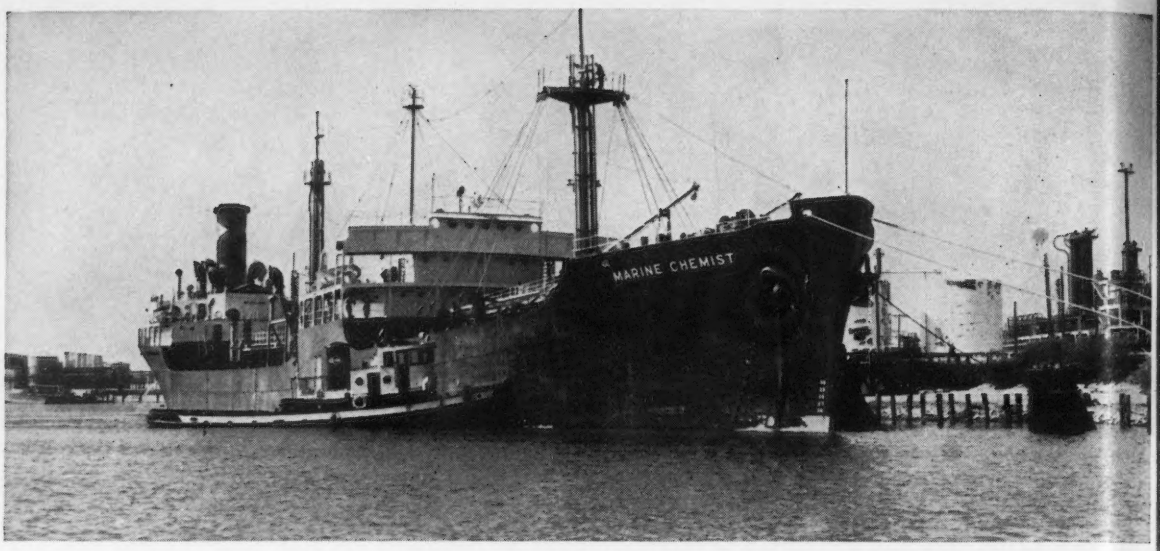


MAGNESIUM ANODES ELIMINATE HULL CORROSION

The S.S. Marine Chemist Demonstrates the Effectiveness of Cathodic Protection

Write today for complete information on marine magnesium anodes.

The S. S. Marine Chemist, Dow's 13,000 ton tanker, has been dry-docked for a complete hull inspection. One year ago, a rail of 106 sixty-pound magnesium anodes was attached to the hull along the trailing edge of the bilge keel on either side of the ship. This cathodic protection was designed for a minimum of one year's service. Now the year is up and...

HERE ARE THE RESULTS!

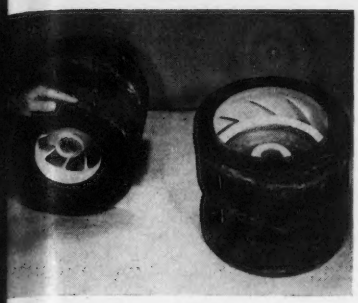
Dry-dock examination reveals: **1. No significant hull corrosion!**

2. No significant pitting of the hull! **3. Anodes are still capable of further service!**

POSITIVE PROOF THAT MAGNESIUM ANODES COMBAT HULL CORROSION.

THE DOW CHEMICAL COMPANY · Magnesium Department · Midland, Michigan.

You can depend on DOW MAGNESIUM ANODES DOW



THIS MONTH'S COVER—Smooth porcelain enamel coatings are fused to interior surfaces of these deep well pump housings by Barrows Porcelain Enamel Co., Cincinnati, Ohio. The glass surface reduces friction and protects the cast iron housing against rust and deterioration. The coating is applied in a single operation.

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Subscription: $9.00 per year to non-members: Member's dues $7.50, of which $3.75 are applied as subscription to CORROSION; Special rate, $4.00 per year for public libraries and libraries of educational institutions. Additional copies to members 50 cents, to non-members, $1.00. Foreign remittances should be by international postal or express money order or bank draft negotiable in the U. S. for an equivalent amount in U. S. funds. Entered as second class matter October 31, 1946, at the Post Office at Houston, Texas, under the act of March 3, 1879.

CORROSION Is Indexed Regularly by Engineering Index.

Corrosion

devoted entirely to
CORROSION
research and control

Published monthly as its official journal, by the National Association of Corrosion Engineers, Inc., at Houston, Texas, U. S. A., as a permanent record of progress in corrosion control.

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Behavior of Ship Bottom Paints Subjected to Cathodic Protection—A Preliminary Study by R. P. Devoluy, C. A. Woolsey Paint & Color Co., Inc.

- **The Association also welcomes at any time constructive discussions of its technical material and technical papers on corrosion for publication in Corrosion.**
- **Interested authors may secure on request a copy of the "NACE Guide for the Preparation and Presentation of Papers" which describes the Association's customs and needs more fully.**

Chapman Casts World's Largest Stainless Gate Valve

9-ton casting produced in austenitic chromium-nickel stainless steel

This valve, produced by The Chapman Valve Manufacturing Co., Indian Orchard, Mass., for the defense effort, is used in corrosive water service. It is stated to be the world's largest, with an overall height of 19 feet, weighing approximately 18,000 pounds. The rough casting weight was approximately 36,000 pounds.

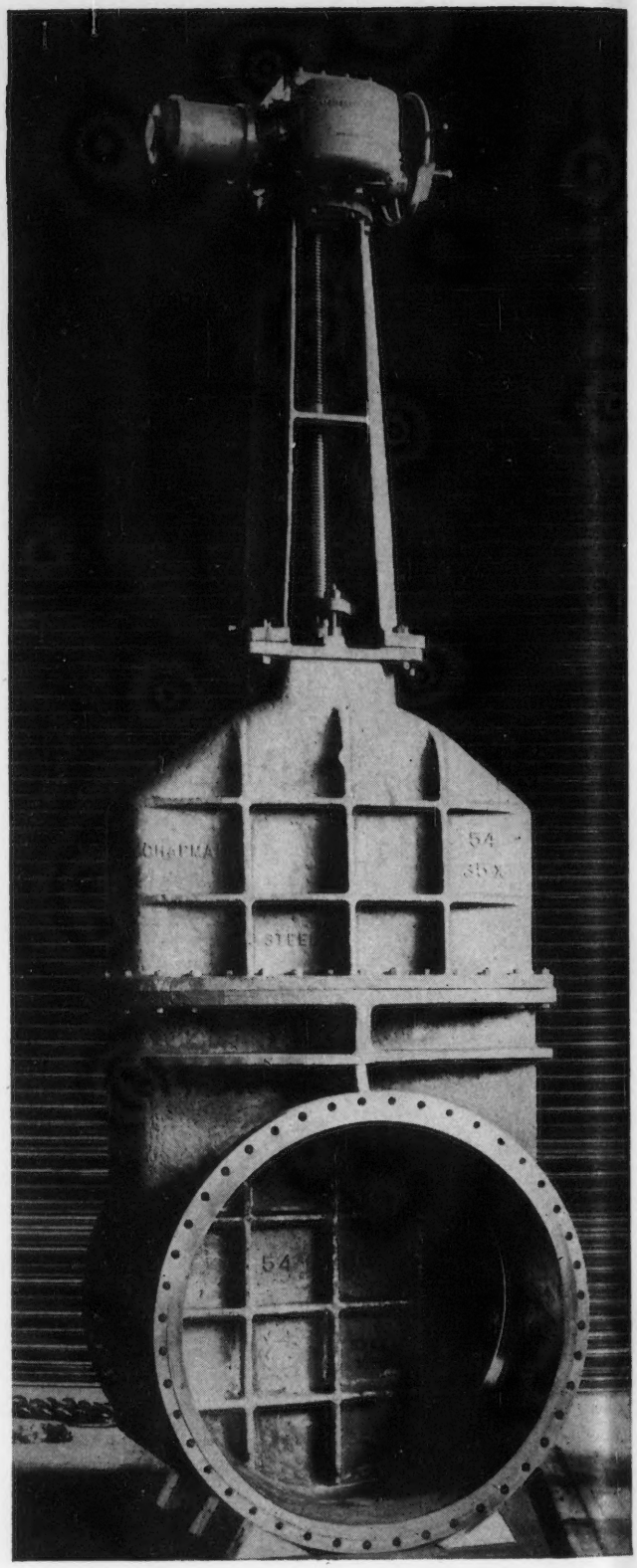
Cast in low carbon 18-8 chromium-nickel stainless steel, it is one more demonstration that size is no limiting factor when you cast parts in stainless steels to provide resistance to corrosion and erosion.

Stainless steel resists attack by nearly all oxidizing acid conditions. In addition, it helps you trim bulk and deadweight without sacrificing strength and safety.

At elevated temperatures, austenitic chromium-nickel stainless steels are distinguished by their strength and outstanding resistance to oxidation. At temperatures down to −320° F. they retain their toughness and unusual strength.

Investigate all the benefits stainless steels can give you. Leading stainless steel companies and foundries produce nickel-containing stainless steels in all commercial forms. A list of sources of supply will be furnished on request.

At the present time, the bulk of the nickel produced is being diverted to defense. Through application to the appropriate authorities, nickel is obtainable for the production of austenitic stainless steels for many end uses in defense and defense supporting industries.



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Ruberoid Air-Vent Felt permits trapped gases to escape through tiny perforations while wrapping pipe.

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TECHNICAL PRACTICES COMMITTEES' DIRECTORY

(Continued from Page vi)

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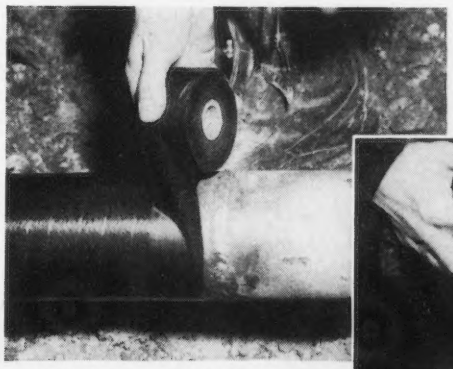

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Complete, uniform coverage of irregular joints and fittings is easy with Dressertape. No gaps, voids or holidays.

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CATHODIC PROTECTION RECTIFIERS...

- ★ AIR COOLED
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- ★ SELF-COOLED WITH HERMETICALLY SEALED STACK
- ★ ADD-A-STACK

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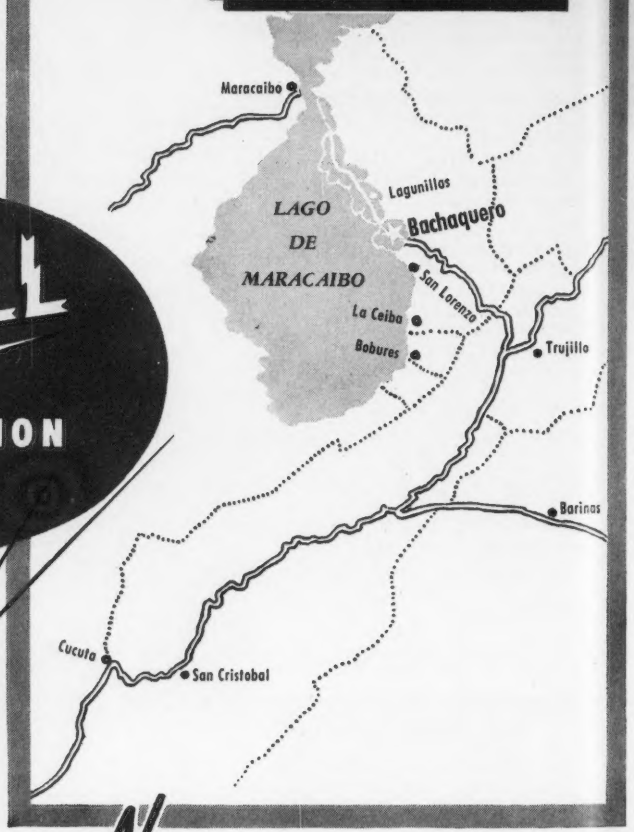

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- Flashing light indicates continuous cathodic condition.
- Can be installed on all makes of rectifiers.
- Visible in daylight 300 yards or more.
- Light can be turned in any direction.
- Designed to indicate failure in either A.C. or D.C. output.

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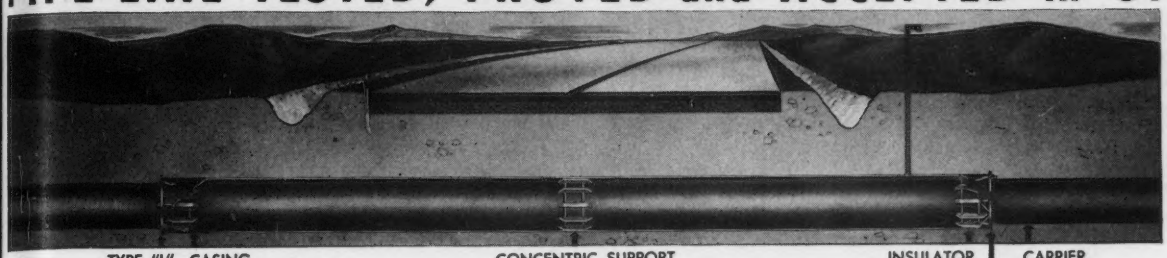
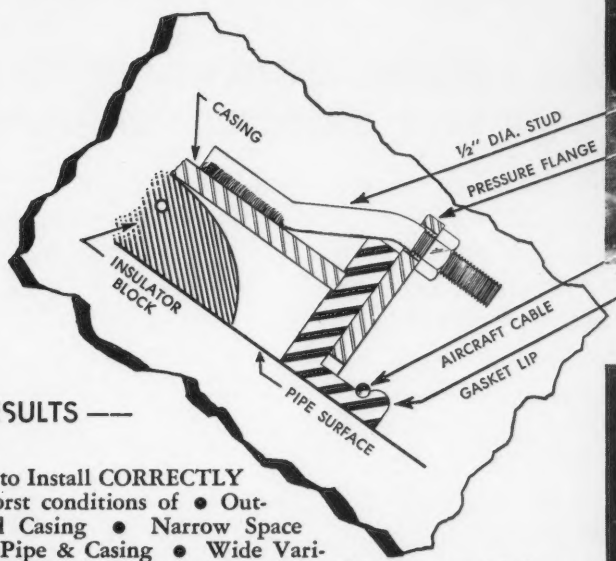
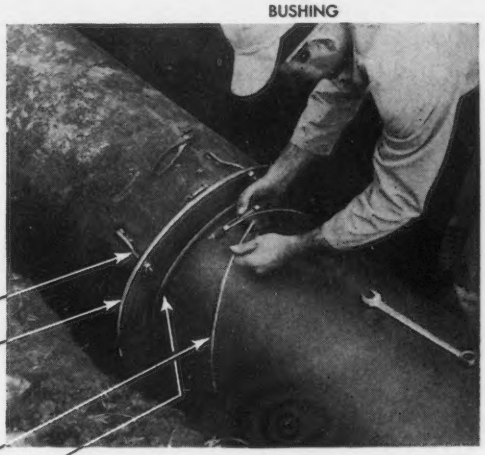


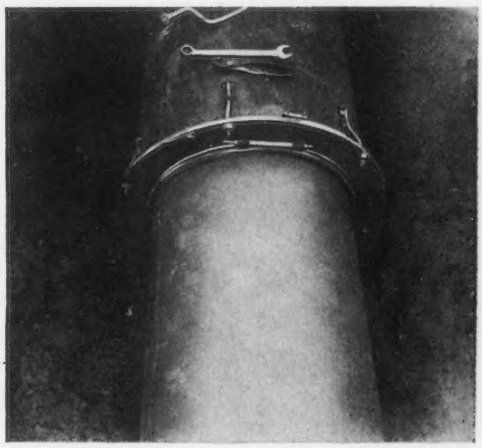
TYPE "L" WmSEAL CASING BUSHING*

A New Design: It BUTTS Against End of Casing Instead of Fitting Inside the Casing.





Assembling cable with rubber-covered union for clamping gasket lip to pipe.



THE COMPLETED INSTALLATION
Note that galvanized cable and union are insulated from pressure flange and from pipe.

RESULTS —

1. Easier to Install CORRECTLY under worst conditions of • Out-Of-Round Casing • Narrow Space Between Pipe & Casing • Wide Variations in Casing Wall and Coating Thickness • Mud • Casing ends beveled — by machine or hand torch.
2. WATER-TIGHT Seal with "L" gasket . . . . . .
   - BUTTED AGAINST CASING as pressure flange is tightened on ½" studs welded to casing.
   - TIGHT TO THE PIPE as aircraft cable (4,600# tensile) is tightened to gasket lip. Union is rubber covered to INSULATE galvanized cable assembly from bare casing structure.
3. Always Insulated from the pipe line when a Concentric-Support Insulator is installed just inside casing after the "drag section" is in place.

AS STRONG & DEPENDABLE AS THE MEN WHO INSTALL THEM

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WRITE FOR BULLETIN 249A

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The ravages of corrosion take an annual toll of $600,000,000 for the maintenance and replacement of underground gas, oil and water pipe. You can protect *your* plant and cross-country piping from silent, vicious corrosion with a **HARCO** designed and engineered protection system.

HARCO corrosion control systems assure longer service life, minimum maintenance and replacement, elimination of "down-time" and protection from the hazards caused by corrosion damage.

To escape the costly fate of corroded pipe lines, call on **HARCO** . . . *first in the field of cathodic protection.*

WRITE TODAY for catalog or call MOntrose 2-2080.

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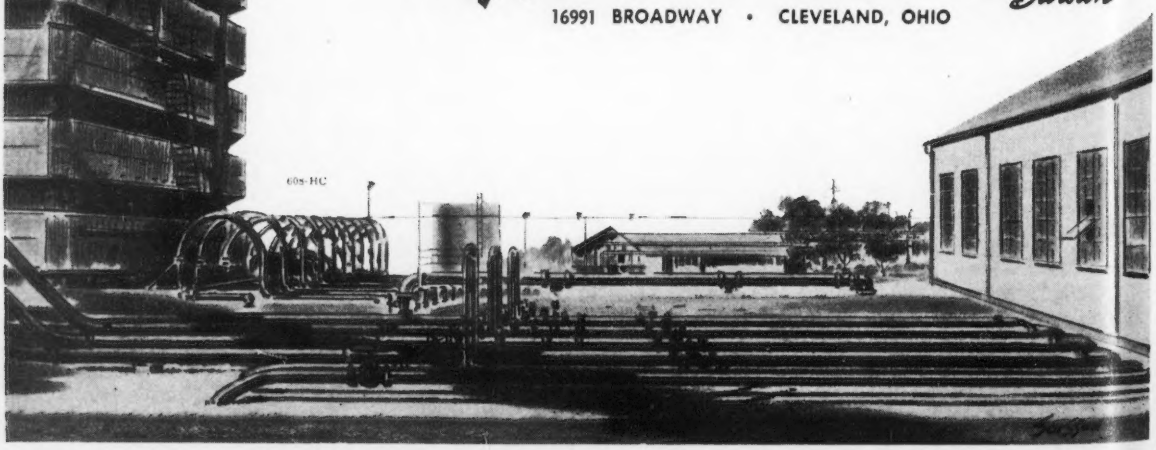
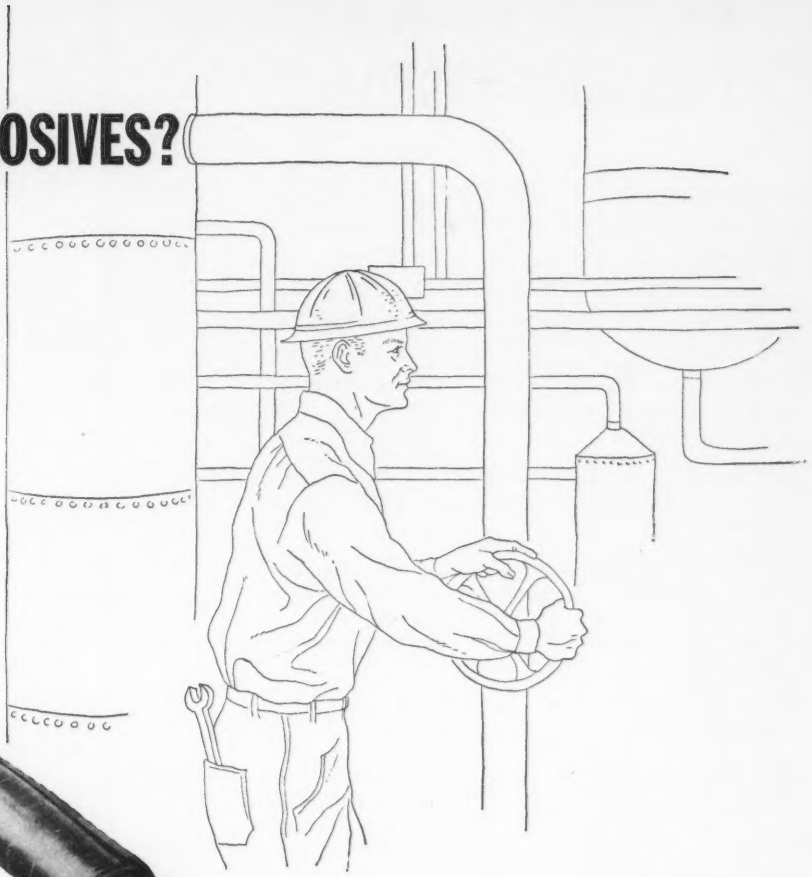
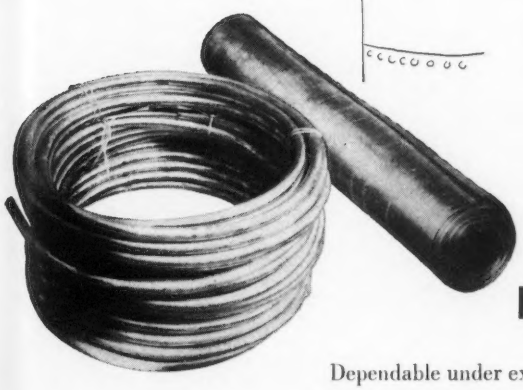


HANDLING CORROSIVES?





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For lead products, use ASARCO Brand lead pipe, lead sheet, and lead fittings. Available in all standard sizes and forms through Federated's 22 sales offices across the country.

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THE NATIONAL ASSOCIATION OF CORROSION ENGINEERS

is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

(a) To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.

(b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.

(c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.

(d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.

(e) To promote standardization of terminology, techniques, equipment and design in corrosion control.

(f) To contribute to industrial and public safety by promoting the prevention of corrosion as a cause of accidents.

(g) To foster cooperation between individual operators of metallic plant and structures in the joint solution of common corrosion problems.

(h) To invite a wide diversity of membership, thereby insuring reciprocal benefits between industries and governmental groups as well as between individuals and corporations.

It is an incorporated association without capital stock, chartered under the laws of Texas. Its affairs are governed by a Board of Directors, elected by the general membership. Officers and elected directors are nominated by a nominating committee in accordance with the articles of organization. Election is by the membership.

Inquiries regarding membership, and all general correspondence should be directed to the Executive Secretary at the administrative headquarters of the National Association of Corrosion Engineers at 1061 M & M Building, No. 1 Main Street, Houston 2, Texas.

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Corrosion

OFFICIAL MONTHLY PUBLICATION

National Association of Corrosion Engineers

An Association of Individuals and Organizations Concerned with Control of Corrosion

1061 M & M Building Houston 2, Texas

Vol. 8 December, 1952 No. 12

Growth of NACE Continues

MEMBERSHIP in the National Association of Corrosion Engineers is expected to exceed 4000 by the end of 1952. This is a gain in membership of better than 23 percent for the year and is a continuation of the rapid growth the association has had since its inception in 1944.

This growth has been accompanied by an increase in local subdivisions, most recently in the area comprising the NACE South East Region, which includes the states of Kentucky, Virginia, North and South Carolina, Georgia, Florida, Alabama, Mississippi and Tennessee. A new section has been organized at Atlanta, while another is contemplated at Jacksonville, Fla. Louisville, Ky., and Birmingham, Ala., are considering new sections. In the West, a new section has been organized at San Diego, Cal., while the application of Canadian members of the association for a Canadian Region is under consideration.

Precepts adopted by the founders of the association have been faithfully followed. The association devotes itself to the collection and dissemination of information about corrosion control by means of meetings and its periodical and other publications.

More than 5000 copies monthly of the association's magazine CORROSION, were distributed during 1952. Numerous section, region and technical committee meetings were held, and the investigative work of the association's technical committees continued and expanded. The NACE Abstract Card Service expects to issue more than 2100 cross-indexed cards on articles published on corrosion in over 500 periodicals the world over.

More persons were registered at the South Central Region's October meeting in New Orleans this year than were registered at the association's 1946 national conference at Kansas City.

These are a few of the many achievements that indicate the healthy growth of the association and the increasing recognition among engineers and management of the seriousness of the corrosion problem. They support also the contention that progress in corrosion control will be speeded by cooperative effort.

As surely as the end of one year marks the beginning of another, it can be said that the continued cooperation of workers in combating the corrosion problem will be fruitful and profitable. There's room for all in NACE, and sincere workers are welcomed to participate in the good work.

Original Articles on Corrosion Sought by NACE

The National Association of Corrosion Engineers welcomes submission of original articles on corrosion for consideration by its editorial review committee as material to be published in Corrosion.

Those who are not familiar with the requirements of the association are invited to write for a free copy of the Guide for Preparation and Presentation of Papers. Attention of younger workers in corrosion is directed to the annual $50 cash award to be given to the author of an article published in Corrosion during 1953. The author must have been 34 years of age or younger during the month in which his article was submitted.

The association also will appreciate having brought to its attention noteworthy articles published in other magazines not generally available to NACE members. An effort will be made to get permission to reprint when such reprinting is judged merited.

Prevention of Corrosion in Cooling Water*

By R. C. ULMER and J. W. WOOD

IT IS NEEDLESS to say that an ample supply of cooling water is of vital importance to many industries today e.g. oil refineries, steam power plants, steel plants, Diesel equipment, etc. The total amount of cooling water has been estimated at well over one billion gallons per minute for all industry. Scale formation and corrosion are the two chief problems involved in cooling water operation.

Although the chief subject of this session is corrosion, in the case of cooling water problems, corrosion and scale formation are so closely related that they are generally considered together. Therefore, some reference is made to scale in the remainder of this paper.

Cooling water systems can be classified as: 1) once-through, 2) open recirculating, and 3) closed recirculating.

Once-through cooling systems are used where plants are small or where large amounts of cooling water are available. The cooling water is "wasted." Such systems are low in initial cost and the problems of scale and corrosion are generally slight. However, where there is a water shortage, e.g. in arid regions and in many large cities, once-through systems are considered "wasteful" and their use is limited. Recirculating systems are being installed in more and more instances.

A typical open circulating system is shown in Figure 1.[1] Spray ponds or cooling towers are used to release the absorbed heat to the atmosphere by evaporation of part of the cooling water. Scale and corrosion problems are encountered with most waters and corrective treatment of some sort is required. Both problems are aggravated by concentration of the impurities in the system. Corrosion especially is severe as the water is "aerated" in the open cooling system.

A typical closed or double recirculating cooling system is shown in Figure 2.[1] Such systems are used where the raw water available contains high total solids or where the supply is limited. In such systems the primary water that absorbs heat from the plant equipment is kept in a closed cycle. The makeup is negligible and pure water may be used or if an impure water is used, treatment is simplified. The secondary water is cooled in a cooling tower and the problems are pretty much the same as for open systems.

Types of Corrosion

Four types of corrosion are commonly encountered,

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1. General attack or where the entire surface of the metal is corroded. Such attack is generally due to a low pH or acid condition, e.g. from sulfur gases or carbon dioxide. Since the attack is general in nature, failures are not common except under severe conditions.
2. Pitting or where the attack is localized. Such attack generally results from the presence of dissolved oxygen or some other localizing effect. Rapid penetration of metal parts may take place leading to failures. In many cases pitting is accompanied by tuberculation. Such corrosion may lead to objectionable deposits as well as metal failure.
3. Micro-biological, sometimes referred to as sulfate reducing bacteria. Such corrosion generally occurs in the form of pits.
4. Stray current electrolysis or where the metal is eaten away, especially where the current leaves the system.

General Aspects of Corrosion Prevention

Corrosion prevention is complicated somewhat by scale or deposit formation. In fact, the simplest means for preventing corrosion is to "promote" formation of a "scale or deposit" on the metal surface. The basis for this, of course, is that unexposed metal will not corrode. The problem is to form a protective film throughout the entire system without forming deposits in objectionable amounts especially in high temperature zones. Much work has been carried out by Langelier,[2] Powell,[3] Larson and Buswell[4] and others. A graph, Figure 3, from the paper by Powell illustrates the method of applying this type of treatment. External treatment, such as the use of softeners, may be necessary.

★ A paper presented at a meeting of Western Region, National Association of Corrosion Engineers, Los Angeles, Cal., November 9, 1951.

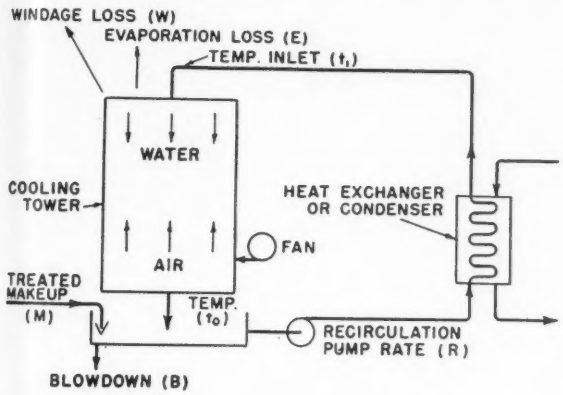
Abstract

General considerations involved in reducing corrosion by the several types of cooling water systems are discussed. The objective of treatment is to form a coating protective against corrosion but not too thick to seriously affect efficiency of heat exchange surfaces. Treatments include pH control, addition of anti-biologicals, insulation to stop stray current corrosion, oxygen removal.

Information on laboratory research on inhibitors by the Drew Company is given. Addition of chromates in correct concentrations stopped corrosion but insufficient amounts caused pitting. Silicate-phosphates gave better results. Mechanism of silica-base inhibitors is discussed. Conclusions reached include the controlled calcium carbonate method requires too close control, chromates are effective in proper concentration but relatively expensive unless small volumes of water are involved. Erratic results were obtained with systems involving complex phosphates at pH 6.0 and chromate-phosphate combinations. Good results were obtained with silicate-phosphate combinations.

In some cases of acid attack adjusting the pH with lime or soda ash may stop corrosion. If hardness is present such adjustment may cause deposit formation as mentioned in the previous paragraph.

In the case of micro-biological corrosion, sterilization or addition of bactericides generally is called for. Such materials as chlorine, phenol compounds



$M = E + W + B$

$E = 1\%\ R$ for each $10°F$ of $(t_1 - t_0)$

$W = 0.2\%\ R$ for forced draft towers

$C =$ Number of concentrations or ratio of $\frac{\text{total solids in B}}{\text{total solids in M}}$

$B = \frac{E - W(C-1)}{C-1}$

Figure 1—Diagram of open recirculating system.

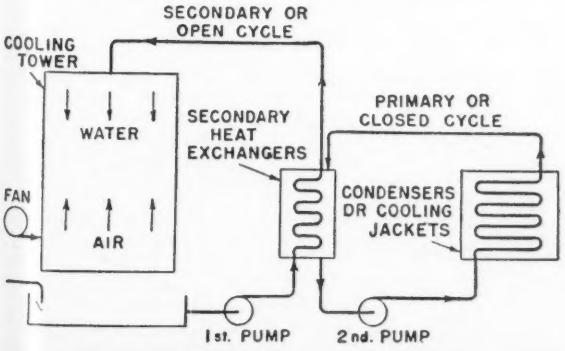
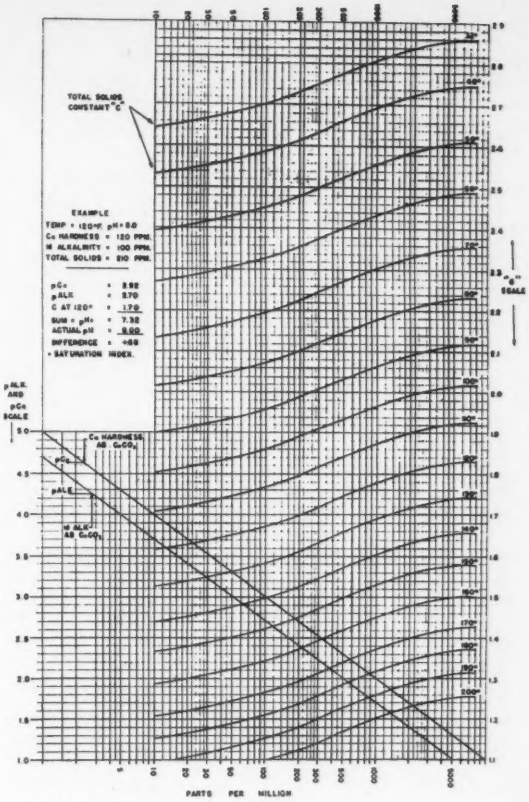


Figure 2—Double or closed recirculating system.



From this chart it is evident that:

(1) Increasing total solids in a water causes both p Ca and p Alk to decrease. This in turn causes pH_s to decrease and consequently causes the index ($pH_a - pH_s$) to increase. Therefore, higher concentrations cause more deposit. For that reason, increased blowoff helps to reduce deposits.

(2) Higher temperatures cause C_t to decrease. This decreases pH_s and also increases the index ($pH_a - pH_s$). Therefore, higher temperatures cause more deposit. That is why scale may form in the hotter parts of heat exchangers while the inlet ends may be clean and may even corrode.

(3) Higher solids increase C_t slightly, counteracting the effect described in Paragraph (1) above. However, this increase of C_t is much less than the corresponding increase in p Ca and p Alk, so that it is still true that higher concentrations cause more deposit.

(4) If Ca is allowed to increase, then the alkalinity must be correspondingly decreased if it is desired to keep the sum (p Ca + p Alk) at any set figure.

Figure 3—Langelier Saturation Index Chart. (From S. T. Powell, Ind. Eng. Chem., Vol. 37, 842 (1945).

and more recently the quaternary ammonium salts may be used. Copper sulfate must be used with care because corrosion may be aggravated by copper plating out on exposed iron parts. Galvanic cells with iron as the sacrificial metal then may lead to serious corrosion.

In the case of corrosion from stray currents the most positive control is to eliminate the current. Prudent use of insulators will sometimes help. Some of the insulating type coatings also may aid, provided the coating does not become porous.

In the case of corrosion from dissolved oxygen, one preventive means involves removal of the oxygen. This can be accomplished mechanically by vacuum deaeration and chemically by the use of oxygen scavengers such as sodium sulfite. Such methods are costly and therefore are applicable only where relatively small amounts of water are involved.

With further reference to dissolved oxygen type

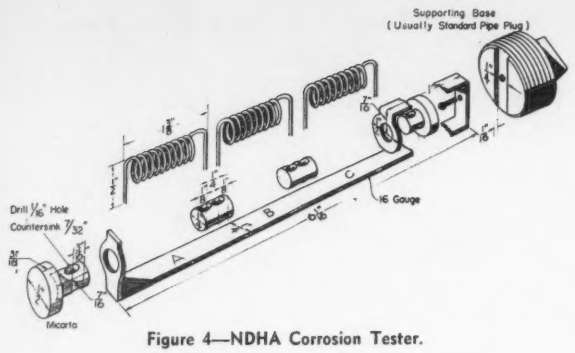


Figure 4—NDHA Corrosion Tester.

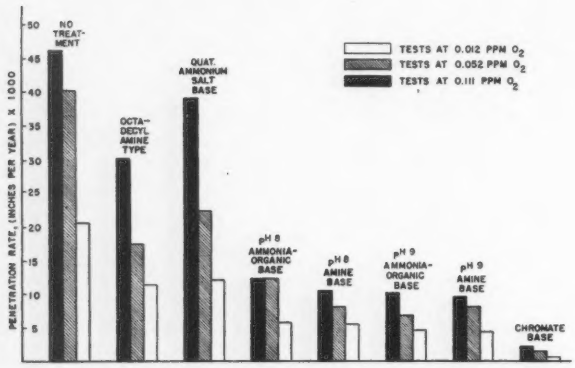

PENETRATION RATE, (INCHES PER YEAR) X 1000
TESTS AT 0.012 PPM O2
TESTS AT 0.052 PPM O2
TESTS AT 0.111 PPM O2
NO TREATMENT
OCTADECYL AMINE TYPE
QUAT. AMMONIUM SALT BASE
pH 8 AMMONIA-ORGANIC BASE
pH 8 AMINE BASE
pH 9 AMMONIA-ORGANIC BASE
pH 9 AMINE BASE
CHROMATE BASE

Figure 5—Corrosion of mild steel by "pure" water: Effect of various inhibitors.

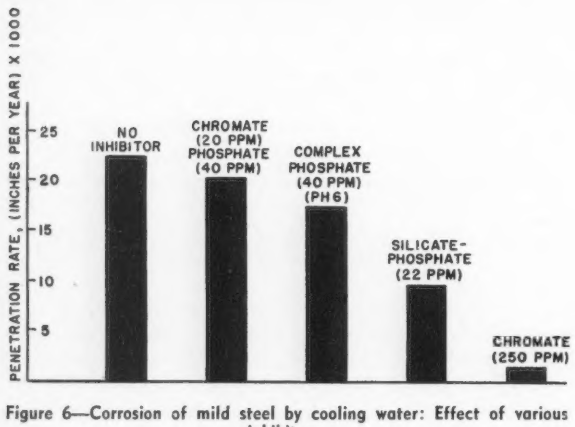

PENETRATION RATE, (INCHES PER YEAR) X 1000
NO INHIBITOR
CHROMATE (20 PPM) PHOSPHATE (40 PPM)
COMPLEX PHOSPHATE (40 PPM) (PH6)
SILICATE-PHOSPHATE (22 PPM)
CHROMATE (250 PPM)

Figure 6—Corrosion of mild steel by cooling water: Effect of various inhibitors.

corrosion, so-called inhibitors have been used to the greatest extent. The formation of a $CaCO_3$ film as inhibitor has already been dealt with. Other inhibitors such as complex phosphates, chromates, silicates, used alone or with organics, all have found wide application. Owing to the lack of clear understanding in the field regarding the use of inhibitors, a research program was started in the authors' company's laboratory some years ago. The remainder of this paper deals with some of the data obtained.

Laboratory Investigation

The work may be divided into two general types of tests: 1) those using pure water simulating distilled or deionized water and 2) those using relatively impure water typical of most cooling waters. In most cases NDHA Corrosion Testers, Figure 4,[5] containing iron (0.1 C), copper (high purity) and brass (60 Cu-40 Zn) coils were exposed to the water. The general analysis of the "pure" water is shown in Table I and that for "impure" water in Table II. The general test procedure has been described previously.[6]

Typical data using the "pure water" are shown in Table III and Figure 5. It should be recalled that the water used in these tests contains very little hardness. Therefore, pH adjustments over a rather wide range were made. With this tester, a penetra-

TABLE I—Characteristics of "Pure" Water Used in Tests

Temperature	180 - 190° F
pH	6.10 - 6.25
Alkalinity	2 - 4 ppm (as $CaCO_3$)
CO_2	7.0 - 8.0 ppm
O_2	0.009 - 0.016 ppm
Fe	Trace
Cu	None

TABLE II—Characteristics of Cooling Water Used in Tests

Temperature	180 - 190° F
pH	6.8
Alkalinity	40 ppm
Hardness	46 ppm
Cl	10 ppm
O_2	2 - 3 ppm
Langelier Index	—1.5

TABLE III—Effect of Various Inhibitors on Corrosion of Metals by Water of Table I

Treatment	O_2 Content	pH	Penetration, ipy x 1000 Steel	Copper	Brass
None	0.012 ppm	6.2	21.0	2.0	1.6
	0.052	5.6	40.0	2.8	3.1
	0.111	5.5	46.0	9.3	10.2
Ammonia-Organic	0.012	8.0	5.2	5.3	4.6
	0.052	8.0	12.0	7.6	8.1
	0.111	8.0	11.3	13.3	12.2
	0.012	9.0	4.1	5.4	11.0
	0.052	9.0	7.0	6.6	15.0
	0.111	9.0	10.2	14.6	11.7
Amine Base	0.012	8.0	5.6	4.5	5.6
	0.052	8.0	8.0	8.7	10.0
	0.111	8.0	12.4	11.8	15.1
	0.012	9.0	4.1	6.6	6.0
	0.052	9.0	8.0	12.0	13.0
	0.111	9.0	9.8	15.2	12.6
Octadecylamine Base (30 ppm)	0.012	6.2	11	1.7	2.4
	0.052	5.6	17	2.4	2.8
	0.111	5.5	30	7.2	8.4
Quaternary Ammonium Salt (20 ppm)	0.012	6.2	12	1.7	2.2
	0.052	5.6	22	2.2	2.0
	0.111	5.5	39	8.9	12.3
Chromate Base (250 ppm CrO_4 =)	0.012	6.1	0.8	0.4	0.3
	0.052	5.6	1.7	0.6	0.8
	0.111	5.4	2.1	0.7	1.2

TABLE IV—Effect of Various Inhibitors on Corrosion of Metals by Cooling Water of Table II

Treatment	pH	Penetration, ipy x 1000 Steel	Copper	Brass
None	6.8	20.2	5.6	6.7
Chromate Base (250 ppm CRO_4)	6.7	1.4	0.4	0.3
Complex Phosphate (40 ppm PO_4)	6.0	17.5	3.6	4.4
Complex Phosphate—40 ppm Chromate—20 ppm	6.8	18.8	4.6	9.2
Silicate—Complex Phosphate—22 ppm—Total	8.9	9.7	4.3	4.0

tion value under 10 is considered as inactive or inappreciable corrosion. While most inhibitors tested were very effective in controlling corrosion only the chromate base reduced the rate to near zero. In this connection it should be noted that chromate, (250 ppm) although effective is too high in cost for all but very small systems. Lower concentrations when used alone or in combination with other products generally are not effective. As indicated by the data, in the case of those inhibitors based on pH control alone, dissolved oxygen concentration must be very low.

Typical data using the "cooling water" are shown in Table IV and Figure 6. Again the chromate base product reduced corrosion to near zero but as pointed out previously maintaining of 250 ppm of Na_2CrO_4 is expensive and applicable only to systems using small amounts of water. Lower concentrations of chromate are not very effective; in fact pitting may occur. Results with "complex phosphate—pH 6.0" and "chromate-phosphate" combinations were erratic and in general poor. In the case of the complex phosphate—pH 6.0 method such results are explained by the fact that even at higher pH's phosphates do not completely prevent corrosion. At lower pH's say 6.0, overall corrosion is still greater although pitting may be reduced slightly. In the case of the chromate-phosphate method again the erratic results can be explained since it is known that low concentrations of chromate sometimes actually increase corrosion, especially pitting.

Silicate-Phosphate Method Good

Much better results were obtained with the silicate-phosphate method. The dosage of this combination does not appear to be as critical as for phosphate alone or for chromate-containing materials. Action of the silicate is to prevent corrosion by film formation. The phosphate aids in this but is especially beneficial in controlling deposits. To limit deposits control of pH may be necessary and in general an acceptable range of pH is 6.5 to 8.0, depending on the water. Results in the field with the silicate-phosphate combination in cooling water and in domestic water as well have been very good and bear out the research data given.

Some discussion of the action of silicates is warranted because these materials generally have been considered scale-forming. It should be emphasized that their corrosion protective action is not due to a film of calcium or magnesium silicate; rather the action is due to an adsorbed film of the silicate. Possibly there is some reaction of the metal with the silicate. For example, in the case of iron or steel, a thin layer of iron silicate would form. Once the metal is coated or covered there will be no further deposition of silica and therefore films of objectionable thicknesses will not form. If sufficient silica is maintained in the water the film will be kept in good "repair" and little if any corrosion will occur. Because certain particular types of silica only are active in controlling corrosion, that silica naturally or initially present in the water is disregarded.

As with all film-forming type corrosion inhibitors some time is required for the film to form, from several weeks to usually a month. During this period the corrosion rate will be decreasing. This must be kept in mind in carrying out corrosion tests. That is, tests should be conducted over several months and preferably several samples should be installed so one may be removed at the end of each month.

Pitting Control Is Considered

Control of pitting also merits some discussion. With most inhibitors general corrosion is less the higher the pH. This, however, is not true in the case of pitting; in fact, pitting generally will be more severe in the pH range 7 to 9 than at a lower pH. The preferred range in the case of the silicate-phosphate combination is 6.0 to 6.5.

As pointed out above, natural silica generally is disregarded, however, where large amounts are present in the water good protection may result and if phosphate is used along with proper pH control excellent corrosion protection will result. This has been found to be the case with the "high silica" waters on the West Coast. That is, use of a complex phosphate, generally with an organic and proper pH control has been found applicable. It should be borne in mind that in this case a silica-phosphate relationship similar to that from a silica-phosphate treatment exists in the water. Therefore the corrosion protection is due to the factors discussed above and referred to in data on the silica-phosphate treatment.

It should not be inferred from the preceding discussion that silica will not cause scale in cooling water systems. It definitely can, but it has been found that if total silica is maintained below 100 ppm, no scale will form even though the calcium and magnesium are very high. Some attention of course is warranted if film boiling takes place or "hot spots" are present but scale or deposits probably would form under such conditions in any case.

Note that *total silica* is referred to. This is determined by the following method.

Suggested Procedure for Determining Total (Crystalloidal & Hydrated) SiO_2

Special reagents: 20% NaOH, phenolphthalein, 1:4 H_2SO_4.

1. Determine SiO_2 by standard Hellige method. This gives crystalloidal SiO_2 in original sample.
2. Treat another sample as follows:
   a. Put 25 ml sample in beaker; add 4 drops of 20% NaOH. Allow to stand 30 min.
   b. Add 1 drop phenolphthalein. Add 1:4 H_2SO_4 dropwise until red color disappears.
   c. Proceed according to usual method for SiO_2.
   d. Silica value is (crystalloidal & hydrated) SiO_2.
3. Determine hydrated SiO_2 as difference between 2 and 1.
4. If procedure 2 gives off-scale reading, repeat steps 2a and 2b; then transfer to 50 ml cylinder and dilute to 50 ml. Take half of this solution, repeat Hellige determination, and multiply result by 2.
5. If sample contains PO_4, add ½ ml of saturated oxalic acid solution before adding molybdate reagent in determining silica.

Finally it should be pointed out that even the "cooling water" must be considered rather "pure" when compared with some waters. However, corrosion data generally are relative and therefore the

data would apply to most types of water encountered. The actual corrosion rates, however, would be different but as pointed out the relative effectiveness of the inhibitors tested still would apply.

Summary

A study has been made of the application of certain corrosion inhibitor systems to the elimination of corrosion in cooling water systems. The controlled calcium carbonate method is applicable in some cases but the method generally does not give effective results because of the close control required, especially where there is considerable temperature variation in the system. Chromate base materials are effective, as would be expected provided the concentration is sufficiently high; that is of the order of 250 ppm. Needless to say the treatment is expensive and therefore applicable only where small amounts of water are involved. Erratic results were obtained with systems involving 1) complex phosphates at pH 6.0 and 2) chromate-phosphate combinations. Good results were obtained with a silicate-phosphate combination and by proper control of pH both corrosion and scale can be controlled in most cases.

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EDITOR'S NOTE—Readers concerned with water corrosion will find twelve papers including one by the authors of this paper presented at ACS Symposium, Sept., 1951, and published in August, 1952, issue of *Industrial & Engineering Chemistry* of interest.

NACE Requirements on Acceptance and Publication of Papers

(Quoted from "Guide for the Preparation and Presentation of Papers." National Association of Corrosion Engineers, 1061 M & M Bldg., Houston 2, Texas.)

These instructions and suggestions govern preparation of papers for publication in CORROSION, and for presentation at meetings of the National Association of Corrosion Engineers. Papers may be submitted for consideration without invitation.

Papers submitted are subject to the publication rules and policies of NACE until released, or unless withdrawn by the author prior to presentation or publication. Papers shall not be a rewrite of material presented elsewhere. The same material shall not be rewritten for presentation or printing elsewhere, except that in some cases an article may be rewritten and pointed toward a particular industry without coming under this restriction. After publication in CORROSION, it is the policy of the Association to give permission to reproduce CORROSION articles verbatim. Such permission shall be requested in writing. Full credit must be given NACE as the original source.

Soil Resistivity Measurements For Corrosion Control*

By F. O. WATERS*

Abstract

Results of experiments to determine most practical soil survey procedure and best equipment are given. Correlation between soil resistivity and corrosion is divided into five classes. Soil corrosivity maps of the area served by Southern California Gas Company were prepared. Details of several types of equipment for determining soil resistivity are given with good and bad points of each. Rules for interpretations of results are listed and the use of soil resistivity determinations indicative to types of coating are outlined.

I. Introduction

THE INCREASING rate and distribution of corrosion leaks has been cause for serious consideration by the oil and gas pipeline industries generally. Therefore an investigation was made to learn of the most practical methods of soil survey procedure and the equipment best suited for the job.

II. Factors Affecting Soil Corrosion

In general there are three principal factors that affect underground soil corrosion: Moisture, salt and/or acid content and aeration.

III. Methods of Determining Soil Corrosivity

The consensus of several authorities is that soil resistivity may be used as a rough index of the corrosivity of alkaline soils.[1,2] No electrical test yet devised appears to offer a generally satisfactory index for corrosivity of acid soils. Fortunately, very little acid soil is found in Southern California Gas Company territory. Therefore resistivity readings can be used in this area without fear of noncorrelation because of the presence of acids.

Soil resistivity as used here means the resistance of a cube of soil expressed in ohms per cubic centimeter.

When the soil is considered as an electrolyte the salt and water content determine the resistance and the aeration will determine the amount of film or oxide deposit.[3] Thus in a localized area the aeration and salt may be considered to be constant, but moisture content may vary from month to month. In any soil where the moisture content changes radically throughout the year resistance of the soil will vary accordingly.[1] It is possible in some soils to have variations in soil resistivity from a minimum of 2500 to a maximum of 10,000 ohm-cm between the wet and dry seasons. In order to overcome these variations three different ways of testing soils have been suggested:

A. Tests should be made in both summer and winter.
B. Tests should be made in winter only.
C. The wet tests method suggested by Allyne[1] should be used. (This method involves pouring water into test holes and allowing the water to soak in for five minutes before measurements are taken. Allyne's tests indicated that these readings will closely approach the minimum readings obtained in the winter time.)

The correlation between soil resistivity and corrosion may be divided into five general classes:

1. Soils with resistivities of 0 to 900 ohm-cms are apt to produce very severe corrosion.
2. Resistivities of 901 to 2300 ohm-cm are classed as severely corrosive.
3. Resistivities of 2301 to 5000 ohm-cm are classed as moderately corrosive.
4. Resistivities of 5001 to 10,000 ohm-cm are classed as mildly corrosive.
5. Resistivities of 10,000 plus ohm-cm are classed as very mildly corrosive.

Whenever there is a marked change in resistivity readings corrosion is likely to occur. For example, when the resistivity is running consistently at 10,000 ohm-cm in one area and in the adjacent area it drops suddenly to 4000 ohm-cm, corrosion is likely to occur in the 4000 ohm-cm area. Or when the resistivity is running at 20,000 ohm-cm and drops to 10,000 ohm-cm corrosion will occur in the 10,000 ohm-cm soil, but at a less rapid rate than in the preceding example.

IV. Scope of Soil Testing Program

In addition to comprehensive soil surveys that have been used to prepare soil corrosivity maps of the entire area served by the Southern California Gas Company, soil resistivity tests are constantly being used in leakage and pipe replacement work, pipe coating specification and cathodic protection station design.

V. Instruments for Measuring Resistivity

A study was then made to determine the instruments best suited for these measurements.

A—One instrument commonly used for soil resistivity measurements is the Shepard Rod.[4] It consists of two Bakelite rods about three feet long, with an indicating instrument, batteries and appropriate keys and switches mounted on one of the rods or canes. The iron electrodes on the ends of the rods have been found to develop less polarization than brass or copper electrodes although more care must be exercised in keeping them bright and free from rust. Since polarization is largely a cathode effect with iron or other ordinary base metal electrodes it can be reduced by making the cathode larger than the anode, thereby decreasing the current density on the cathode. With the rods commonly used today the anode is an iron

★A paper presented at a meeting of Western Region, National Association of Corrosion Engineers, Los Angeles, Cal., June 20, 1951.
* Southern California Gas Co., Los Angeles, Cal.

cone of ½-inch base and ¼-inch in height. The cathode, also an iron cone, has a ¾-inch base and a height of 2⅝ inches.

Advantages

Some of the advantages of this type of instrument are:

1. In soils ranging from 100 to 10,000 ohm-cm there is an accuracy of about 6%[4] which is greater than the average survey requires.
2. The measurements check very well with values obtained using other types of instruments. There is a definite corrolation between the Nipple and Can Test Method and measurements obtained with this instrument.

Disadvantages

Disadvantages of the instrument are:

1. It is necessary to drive two bar holes into the ground.
2. The instrument is more fragile than other soil resistivity measuring instruments.
3. The iron tips of the rods must be maintained free from wear, oil and oxidation.
4. Polarization will affect the readings.

B—Another method of obtaining the soil corrosivity is the Nipple and Can Test.[3] Results obtained from this test give an accurate indication of corrosivity and there is a definite relation between the corrosion indices and soil resistivity. Because of the cost per test this method is now used by our company only for special tests.

C—A third instrument used in soil testing is the Megger Ground Tester.[5,6] This is an ohmeter type instrument designed to measure directly the resistance of a structure to the surrounding earth and the average resistance of the earth to a specified depth. It consists primarily of a hand driven direct current generator, a commutator or current reverser, current and potential coils suspended in a magnetic field, a scale calibrated to read in ohms and a range selector switch.

Advantages

Advantages of this instrument over other types are:

1. Effects of polarization and stray currents are eliminated.
2. The sensitivity and accuracy of a direct current instrument are maintained.
3. The resistivity of the soil can be obtained to any desired depth.
4. The instrument is compact and sturdy and can be used for several other purposes.

Disadvantages

Some of the disadvantages of the Megger are:

1. It must be operated by more highly skilled personnel.
2. It is necessary to contact earth at four places thus making it unsuited for use by leakage crews.
3. Difficulty has been encountered in making contact to earth in some soils.
4. Instrument readings are in ohms and it is necessary to convert to ohm-cm.

D—A fourth type of instrument and the one that is now being used is the single rod Associated Research Soil Resistivity Meter.[7] It differs in principle from the Shepard Rod in that it eliminates polarization through the use of alternating current. Also the case of the probe is used as one electrode and the insulated probe tip is the other electrode thus eliminating the necessity for one of the bar holes. Test results obtained when using the Associated Research Instrument compared favorably with results obtained when using the Shepard Rod.

Advantages

Some of the advantages of using the single rod are:

1. There is only one soil rod, which means only one prospect bar need be driven into the ground. This results in a considerable saving in time and makes the instrument ideally suited for use with gas leakage investigation crews.
2. Polarization potential errors are eliminated.
3. The rod has a slightly smaller diameter than those used in other types of instruments which allows it to fit more easily into a ¾-inch bar hole.
4. The rod appears to be more sturdy and it has a handle which makes it easier to pull out of the ground.
5. The highest reading obtainable with the Shepard Rod is 10,000 ohm-cm while the scale of this instrument goes to 30,000 ohm-cm.
6. Time study during the use of the two rod-type instruments shows that it costs Southern California Gas Company 16 cents per reading with the single rod and 76 cents per reading with the double rod.

Disadvantages

Unsuitable material used in the instrument appear to be the main disadvantages of the Associated Research Instrument used by Southern California Gas Company. The following difficulties have been encountered among 23 instruments:

1. A few of the instruments have developed blisters in the meter dial.
2. It has been necessary to replace several vibrators. This has been done when the meter reading became erratic and would not hold a zero.
3. The permanent magnets lose their magnetism and have to be remagnetized.
4. The switches with which the instruments were equipped were of the push button type and were difficult to operate. We have replaced these with lever switches.
5. Several probe tips have been replaced because of excessive wear and several times the lead wires have been broken near the top of the probe.
6. The batteries were replaced with ones of the same voltage and lighter weight.

These problems have been discussed with the manufacturer and it is understood that the necessary changes will be made.

VI. Interpretation of Results

Miscellaneous factors that should be considered during interpretation of results are:

A Is the line coated or is it bare? If a bare main were in a corrosive soil, it might be less expensive to recondition the line than it would be to install cathodic protection. However if the line had some coating, it might be less expensive, over a period of time, to repair a few leaks and then install cathodic protection than it would be to replace it.

B When considering a thick walled pipe versus a thin walled pipe it might be reasonable to figure that by repairing a few leaks a thick walled pipe installed in moderately corrosive soil would give several years more life before replacement, whereas it would be necessary to replace a thin walled pipe immediately.

C Where the readings are posted on Atlas sheets or strip maps, incorrect posting would cause one area to appear more or less corrosive than it should be.

D Incorrect measurements. Our company has been requested to investigate corrosion in areas where the soil resistivity reportedly was 30,000 ohm-cm and there was no apparent reason for the corrosion. When the resistivity readings were repeated they were found to be more nearly 1500 ohm-cm and the corrosion could be explained.

E Electrolysis. With an area of high soil resistivity the mistake should not be made of assuming that the pipe will not corrode. One factor that would cause severe corrosion in soils of any resistivity is stray current electrolysis from street railways.

F If the measurements are taken too far apart "hot spots" or small areas of highly corrosive soil will be missed and corrosion may appear on a line for which no explanation exists in the available soil resistivity data.

G Gas leakage may dry out soils and indicate higher resistivity than existed prior to the leak. Tests taken on either side of a leak will give more indicative readings in this case.

H Stratification of the soils. All soil resistivity measurements should be taken at pipe depth, otherwise stratification of the soil could cause entirely erroneous interpretation of corrosivity.

I Measurements should not be taken when the soil is super-saturated. For example, if 100 ohm-cm soil were tested with too much 1500 ohm-cm tap water in the test hole, the measured soil resistivity would be higher than the true value.

VII. Use of Soil Resistivity In Determining Types of Coating

Southern California Gas Company uses soil characteristics in determining the type of coating to be used on a pipe line. This is especially true when considering the large transmission lines. The soils, for this purpose, are classified from good to bad as follows:

A. Dry and well drained sand or fine gravel with resistivities of 5000 ohm-cm and above is classed as good and the pipe lines buried in these soils are coated with a single layer coating of filled asphalt or coal tar and Kraft paper wrapper. If rocks are present or the installation is difficult, a mechanical shield is used.

B. Damp, poorly drained loam silt with resistivities of 5000 to 2300 ohm-cm is classed as intermediate. A single layer coating of filled asphalt or coal tar and asbestos wrapper is used on pipelines buried in this type of soil. Again if rocks are present or the installation is difficult a mechanical shield is used.

C. Wet, poorly drained clay or adobe with resistivities of 2300 ohm-cm or less is classed as bad and a heavy duty coating is used. This type of coating consists of 1) Somastic, 2) double layer of filled asphalt or coal tar with Fiberglas reinforcement and an asbestos wrapper, or 3) double layer of filled asphalt with cellulose membrane and an asbestos wrapper.

A mechanical shield is used if rocks are present or the installation is difficult.

The coating on lines buried in this type of soil for any length of time shows evidence of severe soil stress.

VIII. Use of Soil Resistivity Measurements In Cathodic Protection Work

Soil resistivity measurements are one of the prime factors in selecting anodes and in determining voltage requirements for cathodic protection stations.

Southern California Gas Company has arbitrarily set 1000 ohm-cm as the determining factor governing the size of galvanic anodes. The 32-pound anode is installed in soils of 1000 ohm-cm or less. Above 1000 ohm-cm 17-pound anodes are installed.

Southern California Gas Company experience with galvanic anodes installed in soils of more than 2300 ohm-cm is limited, but it is known current output is greatly reduced.

IX. Conclusions

From this information it can be concluded that:

A. The resistivity of the soil is a rough index of corrosivity.

B. Several instruments are capable of measuring soil resistivity with adequate accuracy. The most economical of these instruments, in cost per reading, is the single rod Associated Research Meter.

C. There is sufficient correlation between soil resistivity and corrosion to indicate that the resistivity readings can be of considerable value in leakage work, pipe coating specifications and cathodic protection design when interpreted correctly.

D. Resistivity readings can be obtained economically and their use can result in considerable savings.

References:

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2. Soil Corrosion and Pipe Line Protection, by Scott Ewing. American Gas Association, pp. 82, 83.
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4. Some Theoretical and Practical Data on the Care and Use of Soil Resistivity Rods, by Harry Keeling. *Proced. of the Pacific Coast Gas Assoc.*, **32**, 135 (1941).
5. 'Megger' Ground Testing Instruments, James G. Biddle Co., Catalog 25, (1946).
6. A Manual of Ground Resistance Testing, James G. Biddle Co., Bul. 25-J, (1946).
7. Assorted catalogs and descriptive literature from Associated Research Incorporated, 3758 West Belmont Ave., Chicago 18, Ill.

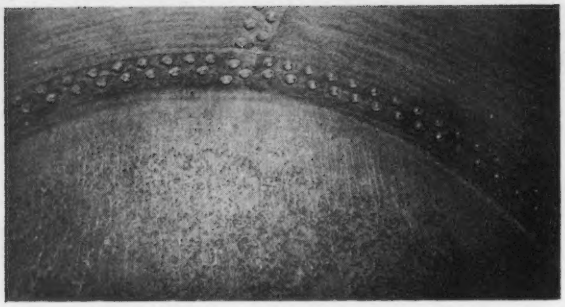

Figure 1—Inner surface of tank car before sodium TCA shipment. Photo shows end plate toward the top of the tank.

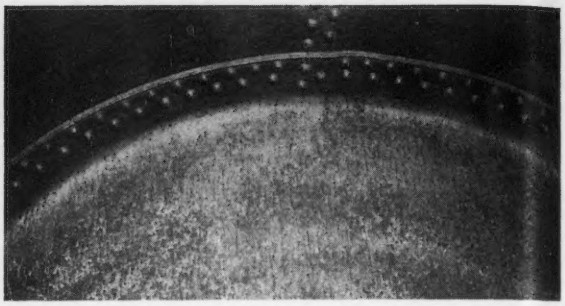

Figure 2—Photograph of the same area of tank car after the sodium TCA shipment.

The Inhibition of Sodium Trichloroacetate Weed Killer Solutions ★

By F. N. ALQUIST and J. L. WASCO

THE WATER-SOLUBLE salts of trichloroacetic acid have been employed as vegetation destroyers and particularly as weed killers for several years. The most widely used salt of the above group is sodium trichloroacetate, more commonly called "sodium TCA." While remarkably effective for the control of vegetation, the uninhibited salt is sometimes objectionable because of its corrosiveness to metals. The object of this report is to record how sodium TCA solutions were made less corrosive by the addition of an inhibitor.

Trichloroacetic acid is usually made by the chlorination of acetic acid in the presence of suitable catalyst.

$$CH_3COOH + 3Cl_2 \rightarrow CCl_3COOH + 3HCl$$

The main impurities in the commercial grade are mono- and dichloroacetic acids. The sodium or calcium salt of the acid is made by reacting the corresponding carbonate or hydroxide with the acid.

Sodium trichloroacetate, in the presence of water, is quite sensitive to heat and to strong alkalis which decompose the sodium salt to sodium bicarbonate and chloroform.

$$2CCl_3COONa + 2H_2O \rightarrow 2CHCl_3 + 2NaHCO_3$$

The corrosiveness of sodium trichloroacetate brought about three distinct corrosion problems: 1) shipping and storage, 2) application, and 3) after effect. These problems are explained below.

1) Shipping and Storage—Sodium trichloroacetate is commonly offered in two forms, 50 percent aqueous solution and 90 percent dry powder. Shipping the 90 percent powder offers no particular corrosion problem. Fiberpaks with separate Saran liners are satisfactory. The uninhibited 50 percent aqueous solution, on the other hand, has a tendency to corrode steel drums and tank cars. Corrosion-resistant metal containers could be used if the right metal were available. Glass carboys could be used, but are definitely a last resort due to their high breakage and freight cost.

★A paper presented at the Eighth Annual Conference, National Association of Corrosion Engineers, Galveston, Texas, March 10-14, 1952.

F. N. ALQUIST—Long interested in corrosion problems, he is a research chemist in the Organic Research Division, Dow Chemical Company, Midland, Mich. He holds a PhD from Purdue (1930) and was instructor in chemistry at Rennsselaer Polytechnic Institute, St. Lawrence University and Purdue. Formerly chairman of the NACE Editorial Review Committee, he is a member of several professional societies and is a frequent contributor of technical material on corrosion.

J. L. WASCO—Since 1939 a research chemist in the Organic Laboratory at the Dow Chemical Company, Midland, Mich., he holds a BS from Michigan State University from which he graduated in 1938. His time is divided between plant corrosion problems and organic research. He is a member of NACE and the American Chemical Society.

Abstract

The addition of small amounts of sodium dichromate to sodium trichloroacetate inhibits the corrosiveness of subsequent solutions on various metals. The presence of an oil layer at the air-liquid interphase prevents much of the liquid-level corrosion.

2) Application—Sodium TCA is usually sprayed onto vegetation as a dilute solution. In many cases it is combined with other selective weed killers such as 2,4-D and 2,4,5-T.

The sprayers used in application of sodium TCA vary in size from the small knap-sack sprayer to the spray train used on railroads. Many different types of metals are incorporated into the sprayers, which are manufactured by many concerns or even built by enterprising mechanically-minded farmers. Steel, galvanized steel and aluminum tanks are most commonly used, although copper, brass, stainless steel and tinned iron are also used extensively in the manufacture of various parts of the spray equipment. Since this spray equipment is already existent and in many cases irreplaceable, the problem resolves itself to making the spray solution noncorrosive to the equipment in normal use.

3) After-Effect—During the spraying of sodium trichloroacetate solutions, many metal surfaces are exposed to the spray solution. Switches and rails along a railroad right of way, tanks and fences at petroleum tank farms and various types of structural metal and metal equipment at substations are a few examples. It is impossible to spray around this equipment without also spraying the equipment.

Despite the above difficulties, the salts of trichloroacetic acid are becoming widely used in grass and vegetation control programs and their great utility makes essential the provision for controlling the corrosiveness of these salts.

The best solution to this corrosion problem seemed to be an inhibitor which could be incorporated into the product and which would render the product less corrosive in shipment, in spray equipment and as a spray residue.

From the start, most of the exploratory research for inhibitors was done on a 50 percent solution of sodium trichloroacetate. If an inhibitor could be found which would inhibit the 50 percent solution, it would more than likely also inhibit the less concentrated spray solution of one or two pounds per gallon.

One of the first tests made was a storage test in a one gallon black-iron drum filled with a 50 percent solution of sodium TCA. Contents of the can were sampled periodically and analyzed for iron:

Time	% FE
Start	0.022
1 Month	0.025
3 Months	0.040
9 Months	0.18

At nine months the drum failed. Examination of the can showed that failure and most of the corrosion occurred either at or slightly above the liquid level, with none below this level.

This storage test showed that future corrosion tests should be made with test specimens only partially immersed so the liquid level and vapor corrosion could be studied.

The testing technique adopted was simple but adequate. A metal strip was placed in a 2-oz. wide-mouth bottle which contained 35 cc of the test solution. One-half of the test strip was immersed, the other half was in the atmosphere above the liquid level. The cap was lightly screwed onto the bottle to simulate storage conditions and to prevent a possible buildup of pressure.

TABLE I—Corrosion Test Data

Conditions: Room temperature, 21 days, specimens one-half immersed, stationary
Uninhibited solution: 50% Sodium TCA
Inhibited solution: 50% Sodium TCA + 0.7% $Na_2Cr_2O_7$

METAL	Corrosion Rates (mils per year)	
	Uninhibited	Inhibited
3S Aluminum	Disintegrated	0.08
Mild Steel	3.58	1.48
Red Brass (85-15)	31.2	0.50
Yellow Brass (70-30)	27.6	0.39
Copper	39.6	8.96
Tinned Iron	0.35	0.02
Stainless Steel (304, 316, 321, 347)	<0.1	<0.1
Galvanized Nails	White ppt.	Less white ppt.

TABLE II—Effect of Oil Layer on Corrosion

Conditions: Stationary, room temperature, 28 days, mild steel specimens 2¾" x 1" x ⅛", one-half immersed.
Solution: 50% sodium TCA

Percent $Na_2Cr_2O_7$	Percent NaOH	cc. Mineral Oil	cc. Amsco HT Oil	Corrosion Rate (Mils per Year)
0.15	0.05	....	....	3.0
0.15	0.25	....	....	3.0
0.15	0.05	5	....	0.6
0.15	0.25	5	....	0.3
....	1.0	....	5	0.1

Mild steel was used almost entirely in this program, with only a few tests on other metals. The mild steel test strips were cut from 1-inch x ⅛-inch stock into 2¾-inch lengths. The burrs were ground off and the specimens numbered with metal dies. The strips were then sandblasted to remove all dirt and mill scale and were stored in a desiccator until used. Most of the other metals were not sandblasted because they were only slightly tarnished. Usual procedure with these latter metals involved scrubbing them with a cleanser and dental-plate brush, rinsing in water and drying them after washing in acetone. The specimens were weighed to 0.001-gram before the test.

After the test, the corrosion products were scraped from the strip with a spatula. The specimens were scrubbed with cleanser and dental-plate brush and any remaining corrosion product in cavities was removed with a sharp-pointed tool. The strips were rinsed with water, dried after immersing in acetone and reweighed.

The weight loss of the metal was calculated to mils penetration per year using the following formula

$$\text{mpy} = \frac{535{,}000\ g.}{MAT}$$

where g = grams loss
M = sp. gr. of metal
A = sq. in. surface area
T = hours exposure

Visual appearance of the strip was considered as important as corrosion rate and any pitting of the test specimen was noted.

Test Results

A considerable number of compounds and com-

mercial products were tried as inhibitors for sodium TCA solution corrosiveness on mild steel. Sodium chromate and sodium dichromate were selected as the best of all the inhibitors tested. In comparative tests, these two chromium compounds were found to be equally effective as sodium TCA inhibitors.

Table I shows the effect of the addition of a slight amount of sodium dichromate to sodium TCA on the corrosion of various metals. The effect was especially pronounced on aluminum. The uninhibited sodium TCA solution reacts with aluminum quite readily forming a voluminous mass of white precipitate. In a day or two, the aluminum is completely disintegrated. This reaction is stopped completely by the addition of sodium dichromate. Yellow and red brass are more effectively inhibited than copper. The tin coating on steel was not attacked at all by the uninhibited sodium TCA solution; the 0.35 mils per year corrosion rate recorded is the action of the solution on the iron exposed at the sheared edges of the test specimen. This action was effectively controlled by the inhibitor. The stainless steels listed in Table I are resistant to uninhibited sodium TCA solutions. Galvanized nails were used to check the corrosiveness of sodium TCA on galvanized steel. Corrosion rates were impossible to obtain due to a heavy adherent white precipitate which formed on the surface. A lesser precipitate formed in the inhibited solution.

Much of the corrosion of the metals in sodium TCA solutions is concentrated at the liquid level. Some tests were made to determine whether a layer of oil over the sodium TCA solution would interfere with this corrosion. The data in Table II are typical of that obtained. The presence of the oil at the interphase prevents the corrosion at this level.

On the strength of the above test data, a 10,000 gallon tank car of 50 percent sodium TCA was shipped to an Eastern seaboard railway terminal. This was a test shipment and was watched very closely. The solution contained 0.5 percent sodium dichromate based on the dry weight of the sodium TCA.

Before the car was filled, it was washed and dried thoroughly. Then a photograph (Figure 1) was taken of the inside surface toward the top of one end of the car.

Fifty-five gallons of Amsco HT oil was put into the car. The car was filled with a 50 percent sodium TCA solution inhibited with sodium dichromate and made slightly alkaline. The oil, being lighter than the aqueous solution, remained on top of the liquid as the car was filled. This procedure allowed the entire inner surface of the tank car to be wet with oil before being exposed to sodium TCA. The car was shipped with instructions to the consignee to return the empty car immediately. The car was rewashed and photographed (Figure 2) upon its return, forty days after the first photos were taken. These photos and a close visual examination of the car showed that no corrosion occurred in shipment.

Since this test shipment in 1950, many more tank cars of 50 percent sodium TCA have been shipped in a like manner.

The sodium dichromate and a mild alkalizing agent have been added to the commercial 90 percent sodium TCA powder. The inhibitor is thoroughly admixed during production to insure a uniformly inhibited product.

Conclusions

The corrosion of aluminum, mild steel, brass, copper and galvanized steel by sodium TCA solutions can be inhibited by the addition of small amounts of sodium dichromate ($Na_2Cr_2O_7$) to the sodium TCA. Aluminum, which has the highest corrosion rate in uninhibited sodium TCA, is almost completely protected by the sodium dichromate inhibitor.

Much of the liquid level corrosion of metals by sodium TCA solutions can be eliminated by an oil layer at the liquid-air interphase.

DISCUSSION

Discussion by George E. Best, Mutual Chemical Co. of America, Baltimore, Md.:

The information so well presented in this paper is especially valuable in that it will help to dispel the somewhat prevalent idea that hexavalent chromium inhibitors are unsatisfactory in organic media on account of reactivity as an oxidizing agent. This is an excellent illustration of the fact that there are many organic systems where advantage can be taken of chromate's protectiveness to metal. In view of the present scarcity of published information, however, it usually is necessary to make trials under the specific conditions of proposed use. Will the paper as published include data concerning the rate at which the inhibitor is consumed?

Reply by J. L. Wasco:

We are sorry to state that no study was made of the rates of depletion of the inhibitor.

Effect of Titanium in Galvanic Corrosion*

By HENRY PAIGE and SARA J. KETCHAM

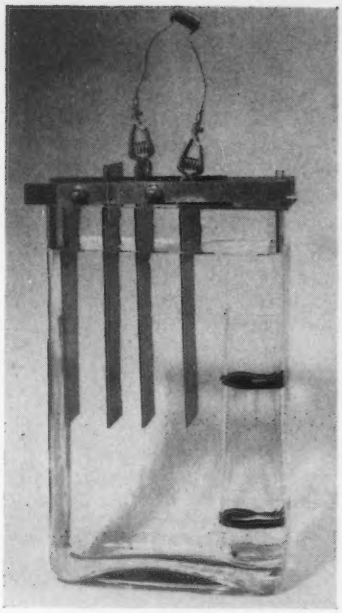

Figure 1—Corrosion cell.

Introduction

IN RECENT YEARS, the availability of titanium and titanium alloys on a semi-commercial basis has provoked much discussion and experimentation to determine their characteristics.[1-4] Thus an impressive array of data on the physical and chemical properties of these alloys has been rapidly compiled, among which are those dealing with the remarkable resistance of titanium to chemical attack or corrosion in many reagents and environments.[5] Furthermore, as seen from Table I, titanium alloys have densities approaching aluminum alloys, but possess the mechanical properties of steels. Unfortunately, titanium falls short of being the "perfect metal" because of its lack of resistance to oxidation and embrittlement at elevated temperatures.

Inasmuch as weight reduction is an important consideration in the design of aircraft, the possibility of utilizing titanium alloys in place of stainless steels is appealing. Interchangeability, however, would depend, among other things, upon comparison of the galvanic action produced on other aircraft metals when in contact with either titanium or stainless steels in marine environments.

Materials

For the determination of coupled corrosion effects, galvanic couples were set up between titanium or stainless steel and representative metals and alloys with which they conceivably could come into contact in aircraft components. These metals are:

Alclad 75S-T6 Aluminum	Copper
75S-T6 Aluminum	Steel (4130)
24S-T3 Aluminum	Inconel
2S-H14 Aluminum	Magnesium (J1-h)
3S-H14 Aluminum	Nickel
52S-H14 Aluminum	Lead
61S-T6 Aluminum	Tin
Brass (60-40)	Zinc
Cadmium (plated on steel)	

Commercially pure titanium was obtained in sheet form from the Bureau of Mines and designated by them as Sheet Number S34B. A 1.8% Cr — 0.9% Fe alloy of titanium, [Ti-150A], was obtained from the Titanium Metals Corporation in the form of ten (10) panels, each 2 inches x 6 inches x 0.040-inch. For comparative purposes, a titanium stabilized 18-8 Type 321 stainless steel was used (0.052-inch).

*Submitted for publication January 21, 1952.

HENRY PAIGE—Acting head of the Surface Treatment and Corrosion Section of the Aeronautical Materials Laboratory at the Philadelphia Naval Air Material Center, he holds a master's degree in science (1949) from Massachusetts Institute of Technology received after completing a thesis titled "Nature of Passivity in Stainless Steels." His work includes studies on electroplating, metal cleaning and descaling, oxidation and corrosion prevention, stress corrosion and chemical surface treatments. He formerly worked for the Arma Corp. on problems associated with electronic components.

SARA J. KETCHAM——Metallurgist in the Surface Treatment and Corrosion Section of the Aeronautical Materials Laboratory, Naval Air Material Center, Philadelphia, she is engaged in research and development work in the field of corrosion and protective coatings for aircraft. A graduate of Bryn Mawr College, she formerly was employed in the Metallurgical Division of the Industrial Test Laboratory at the Philadelphia Naval Shipyard.

Abstract

While titanium has remarkable corrosion resistance in many environments, other factors have to be considered before this metal can be used in naval aircraft construction as a replacement for stainless steels. Among these are galvanic effects which could result from contact with dissimilar metals in marine atmospheres. A series of laboratory tests has been performed in which various metals have been coupled to either stainless steel or titanium in normal sodium chloride. Electrode potential studies have also been made on specimens given different surface treatments. Comparison of the data indicates that the electrochemical behavior of titanium and stainless steel is similar under the test conditions. Mechanical testing of heat treated specimens reveals that exposure to oxidizing conditions above 1000 degrees F has a deleterious effect on the ductility of titanium as well as its resistance to stress-corrosion conditions.

Experimental Procedure

A. *Weight Loss and Corrosion Current Measurements.*

Specimens in the form of panels, either 6 inches x 2 inches or 5 inches x 1½ inches, were fabricated from the various materials for use in coupled corrosion tests. These were degreased, abraded with 180 grit emery cloth and steel wool and rinsed in distilled water and acetone prior to weighing. Metal surfaces were stopped off with a 50 percent beeswax-50 percent rosin mixture so that 100 sq. cm. was exposed to the corrodent. Four panel specimens, two of titanium or two of stainless steel and two of the metal under comparison were then supported one inch apart in an aerated one normal sodium chloride solution by means of a Bakelite fixture. The test solution was maintained at 30 degrees C ± 0.5 degrees in a three liter jar by means of a thermostatically controlled water bath. One pair of dissimilar metals was coupled together by means of a calibrated fixed 1-ohm resistor and the other pair left uncoupled (Figure 1). Duplicate tests were run on all combinations.

During the 2-day test period, the potential drop across the fixed resistance was measured after intervals of 1 hour, 4 hours, 24 hours and 48 hours. Corrosion currents were then calculated by Ohms Law (E=IR). On completion of the exposure tests, the specimens were cleaned in trichlorethylene to remove the beeswax-rosin mixture and treated further to remove the products of corrosion in a solution formulated for the specific metal:

1. Aluminum alloys, Inconel, stainless steel and titanium—immersed for one minute in concentrated nitric acid and scrubbed lightly with a bristle brush.
2. Steel—immersed five minutes in boiling 20 percent sodium hydroxide to which was added 200 grams/liter of zinc dust.
3. Magnesium—immersed fifteen minutes in boiling 15 percent chromic acid plus 1 percent silver chromate.
4. Tin—immersed ten minutes in boiling 15 percent tri-sodium phosphate and scrubbed lightly with bristle brush.
5. Lead—immersed ten minutes in boiling 1 percent acetic acid.

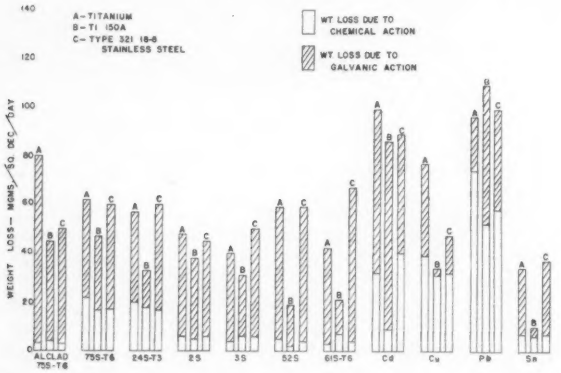

Figure 2—Total weight loss of anodic metals coupled in aerated NaCl.

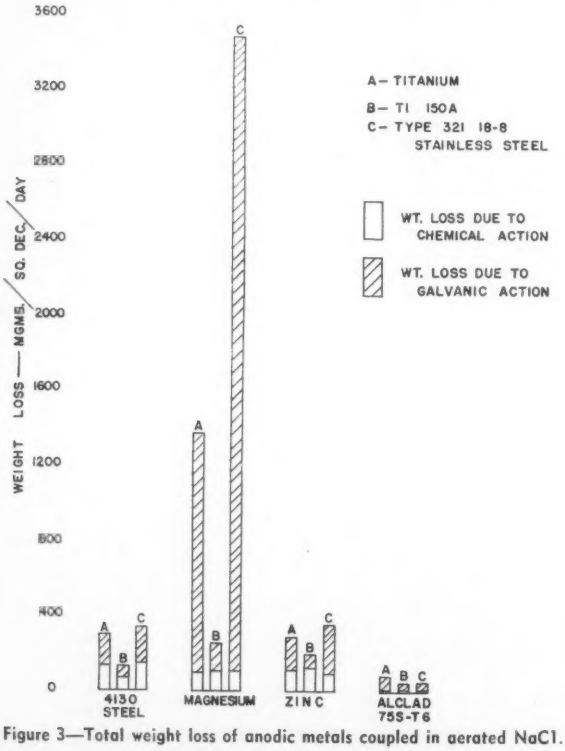

Figure 3—Total weight loss of anodic metals coupled in aerated NaCl.

TABLE I—Mechanical Properties of Various Alloys

ALLOY	Density (gr/cm³)	Ultimate Tensile Strength (psi.)	Yield Strength (psi.)	Percentage Elongation
Titanium (1.8% Cr-0.9% Fe)	4.7	156,000	148,000	14.5
Titanium (Commercially pure)	4.5	90,000	80,000	20
Titanium (7% Mn)	4.7	150,000	140,000	12–15
Titanium (4% Mn-4% Al)	4.7	150,000	140,000	15
Al 24S-T3	2.77	64,000	42,000	15
Al 75S-T6	2.8	73,000	63,000	5
Stainless Steel (321)	8.2	90,000	40,000	60

TABLE II—Summary of Coupled Weight Loss Determinations

Duration of Test—48 hours Solution—Aerated $\frac{N}{1}$ NaCl

Temperature—30° ± 0.5° C

Anodic Metal	Coupled to Stainless Steel		Coupled to Titanium		Coupled to Ti-150A	
	Wt. Loss mdd*	Current Milli-amps	Wt. Loss mdd	Current Milli-amps	Wt. Loss mdd	Current Milli-amps
Alclad 75S-T6	50	5.5	80	6.0	45	3.7
75S-T6	60	5.0	62	4.6	47	3.3
24S-T3	60	4.4	57	3.5	33	2.8
2S-H14	45	4.2	48	4.5	38	3.4
3S-H14	50	6.2	40	4.0	31	2.9
52S-H14	59	5.7	59	5.5	19	1.3
61S-T6	67	6.5	42	4.1	21	1.0
Brass (60-40)	21	0.04	26	0.03	20	0.00
Cd	89	2.3	99	1.7	86	0.85
Cu	47	0.08	77	0.02	34	0.00
Fe (4130)	340	5.5	300	5.1	130	2.7
Inconel†	0	0.0	0	0.0	0	0.0
Mg (J-lh)	3475	171	1480	75.0	256	39.0
Ni	2	0.0	3	0.0	2	0.0
Pb	99	0.57	96	0.38	109	0.3
Sn	37	0.92	34	0.31	10	0.00
Zn	351	8.8	283	3.4	195	2.4

Average Corrosion Rate of 18-8..... 0.50 mdd*
Average Corrosion Rate of Titanium..... 0.25 mdd
Average Corrosion Rate of Ti-150A..... 0.29 mdd

* Milligrams per square decimeter per day.

† Inconel initially cathodic to titanium, 150A and stainless steel, but negative currents of about 0.01 ma dropped to zero after 4 hours.

6. Cadmium—scrubbed with bristle brush and pumice.
7. Copper, brass and nickel—immersed two minutes in 18 percent hydrochloric acid and scrubbed lightly with bristle brush.
8. Zinc—immersed five minutes in boiling 10 percent ammonium chloride and twenty seconds in boiling 5 percent chromic acid plus 1 percent silver chromate.

After cleaning the metals were rinsed, dried in acetone and re-weighed. The rate of corrosion was then calculated in terms of milligrams lost per square decimeter per day. An arithmetic average was also taken of the corrosion current readings for each couple.

B. *Stress Corrosion Exposure*

Strip specimens of Type 321 stainless steel and the Ti-150A alloy, 6 inches x 3/8-inch, as received and heat treated for 48 hours at 500 degrees F and 1020 degrees F, respectively, were employed for these tests. The strips were stressed as simple beams to a value of 25,000 psi at the outer fibers and subjected in duplicate to exposure in synthetic sea water[6] for five hours at 140 degrees F. Tensile specimens, from these as well as heat treated but untested strips, were then machined with a 2-inch gage length and pulled in tension.

C. *Electrode Potential Measurements*

A set of three panels of Ti-150A alloy was abraded with emery cloth and steel wool to mechanically activate the surface, then rinsed in distilled water for one minute and immersed in air-saturated one normal sodium chloride solutions at 30 degrees C. Solution potentials were measured at intervals with a Fisher Type S potentiometer, a N/10 calomel electrode being used as a reference. Upon completion of 72 hours' exposure, the electrodes were surface treated in one normal hydrochloric acid for 30 minutes, rinsed and re-immersed. A third run was made after the specimens were anodized in a 5 percent chromic acid solution for 15 minutes at 40 volts and rinsed.

Results

Inasmuch as weight loss was used as a basis for comparing titanium to stainless steel, a summary of their galvanic effects is presented in Table II. In general it can be seen the metals under investigation produced effects of a comparable magnitude on the various alloys tested. However, these data include the loss due to chemical solution as well as the loss due to the galvanic current. When the amount of metal attacked by the solution, as determined from the uncoupled panels, is subtracted from the total attack, the loss due to the current is determined. A breakdown of the data in this manner is shown as an example in Table III, wherein the measured weight loss is compared also to the quantity calculated from the average current flow by Faraday's Laws. Both sets of values show good agreement.

Pictorial comparison of the chemical and galvanic attack measured in these experiments is presented in Figures 2 and 3. Here it is clearly evident that titanium is as good as if not superior to stainless steel in desirable galvanic properties. The reduction in cor-

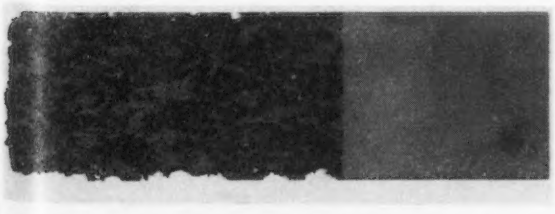

Figure 4—Magnesium panel after coupled corrosion test.

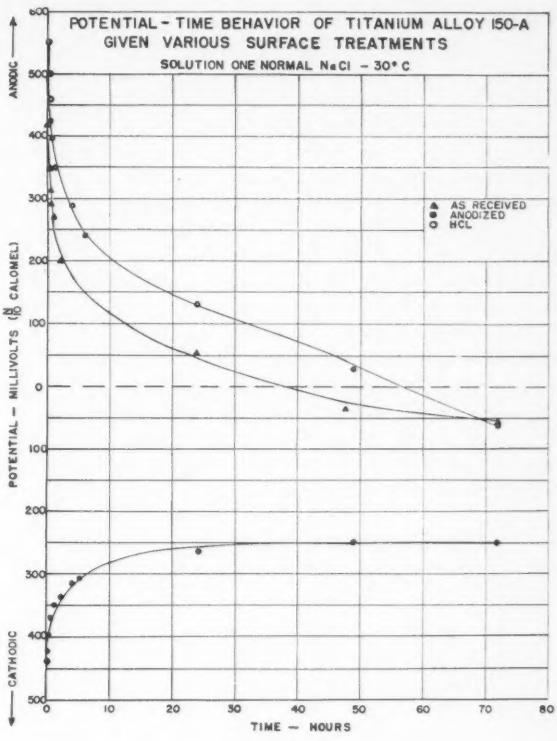

Figure 5

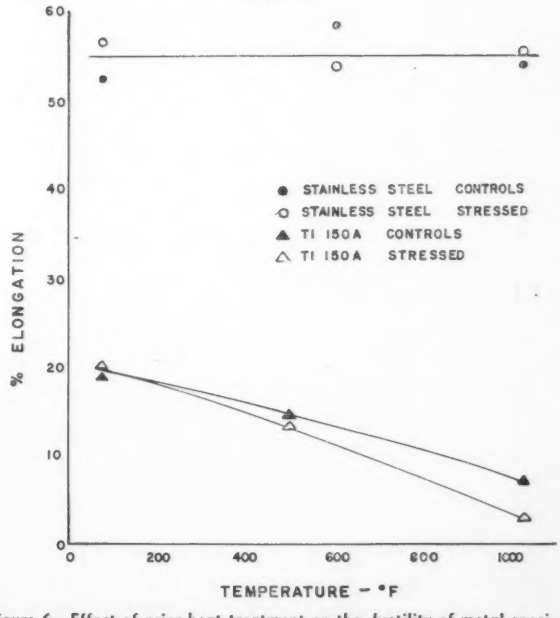

Figure 6—Effect of prior heat treatment on the ductility of metal specimens when tested after exposure to conditions of stress corrosion.

rosion current and weight loss obtained with the Ti 150A indicates it polarizes more readily than the others under the test conditions.

One of the most practical methods of appraising the severity of galvanic attack occasioned by coupling two dissimilar metals is to convert the weight loss data into inches penetration per year. This method will give an indication as to when mechanical failure may occur due to the decrease in cross-section. Thus as seen from Table IV, magnesium corrodes at a rapid rate and heavy sections could be destroyed in a short time. Furthermore, although the weight losses appear small for aluminum alloys, due to their low specific gravity the amount of metal removed places them high in the table denoting severity of attack.

Another factor also must be taken into account in predicting the service life of a coupled metal. If pitting occurs, faster failure will be caused by localized attack. This is particularly the case with magnesium which developed deep pits and perforations during the two-day test period (Figure 4). All the aluminum alloys exhibited pitting attack in a lesser degree. It is therefore probable these alloys would likewise fail by perforation before reduction in weight would become significant.

In conjunction with the corrosion data, it was considered that the solution potential behavior of titanium would be of interest. The curves in Figure 5 show that mechanical abrasion activated the surface, but the Ti 150A alloy slowly regained its passivity in sodium chloride in the presence of oxygen. Such behavior likewise occurred when the surface was activated by means of acid immersion. Anodic treatment initially produced a very passive potential which then reached a less passive steady state. Activation of stainless steel by mechanical abrasion or pickling and passivation in nitric acid also results in similar electrode potential behavior.[7]

A final comparison of titanium with stainless steel is shown in Table V. Whereas neither heat treatment nor stress corrosion exposure adversely affected the steel, the Ti 150A alloy suffered diminished ductility. As seen in Figure 6, the percentage elongation decreased from 19.5 percent to 7 percent as a result of exposure to a temperature of 1020 degrees F. Furthermore, exposure to stress corrosion conditions, after thermal treatment at this temperature, resulted in a further decrease in ductility to a value of 4 percent. Examination of the titanium specimens at 1000X revealed no discernable changes in the microstructure which could account for the reduction in ductility. All the structures showed longitudinal grains of primary alpha contained in a matrix of acicular alpha.

TABLE III

Weight Loss Values for Metals Tested With Titanium Alloy 150-A

METAL	Uncoupled Weight Loss mdd*	Coupled Weight Loss mdd*	Average Current Values Milliamps	Calculated Weight Loss Due to Current mdd*	Actual Weight Loss Due to Current mdd*
Alc 75S-T6	4	45	3.7	30	41
75S-T6	17	47	3.3	27	30
24S-T3	18	33	2.8	22	15
2S-H14	5	38	3.4	27	33
3S-H14	6	31	2.9	24	25
52S-H14	2	19	1.3	10	17
61S-T6	7	21	1.0	9	14
Brass (60-40)	22	20	0.0	0	0
Cd	9	86	0.85	42	75
Cu	31	34	0.0	0	3
Fe (4130)	72	130	2.7	68	58
Inconel	0	0	0.0	0	0
Mg (J-lh)	103	256	39.0	431	153
Ni	3	2	0.0	0	0
Pb	49	109	0.3	32	60
Sn	6	10	0.0	0	4
Zn	125	195	2.4	122	70

* mdd—milligrams per square decimeter per day.

TABLE IV—Severity of Galvanic Attack

Coupled to Titanium	IPY*	Coupled to Ti-150-A	IPY*	Coupled to Stainless Steel	IPY*
Magnesium (J-lh)	1.24	Magnesium (J-lh)	.212	Magnesium (J-lh)	2.87
Zinc	.058	Zinc	.040	Zinc	.071
Fe (4130)	.055			Fe (4130)	.062
Alc 75S-T6	.040	75S-T6	.026		
		Fe (4130)	.022	61S-T6	.036
75S-T6	.033	2S-H14	.022	52S-H14	.032
52S-H14	.033	Alc 75S-T6	.022	75S-T6	.031
24S-T3	.029	24S-T3	.018	24S-T3	.031
2S-H14	.026	3S-H14	.018	Alc 75S-T6	.026
3S-H14	.022			3S-H14	.026
61S-T6	.022	Pb	.016	2S-H14	.024
Cd	.018	Cd	.015		
		52S-H14	.011	Cd	.015
Cu	.012	61S-T6	.011	Pb	.013
Pb	.011				
		Cu	.005	Cu	.008
Sn	.007	Brass (60-40)	.004	Sn	.007
Brass (60-40)	.004	Sn	.002	Brass (60-40)	.004
Ni	.000	Ni	.000	Ni	.0003
Inconel	.000	Inconel	.000	Inconel	.000

* IPY—Inches penetration per year.

Conclusions

Based upon a laboratory evaluation of galvanic corrosion, it has been shown that titanium alloys and stainless steels are similar in their electrochemical behavior. However, due to the reduction in mechanical properties and greater susceptibility to corrosion occurring at elevated temperatures, the interchangeability of titanium for stainless steels appears to be limited to parts functioning substantially below 1000 degrees F. Nevertheless, it is apparent that many components can be fabricated with these lighter alloys without any undue deleterious effect and that titanium and titanium alloys are slated to play an ever increasing role in the construction of aircraft.

This paper represents only the personal views of the authors and in no way reflects the official attitude of the United States Navy.

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TABLE V—Results of Stress Corrosion Tests

ALLOY	Heat Treatment	Test Conditions	Tensile Strength PSI*	Percent Elongation in 2"*
Ti-150-A	None	Unexposed	154,400	19.5
Ti-150-A	None	Stress Corrosion Exposed	154,900	20.7
Type 321 18-8	None	Unexposed	89,200	52.3
Type 321 18-8	None	Stress Corrosion Exposed	87,950	56.5
Ti-150-A	500° F-48 hrs.	Unexposed	157,000	14.8
Ti-150-A	500° F-48 hrs.	Stress Corrosion Exposed	158,500	13.5
Type 321 18-8	500° F-48 hrs.	Unexposed	94,800	58.3
Type 321 18-8	500° F-48 hrs.	Stress Corrosion Exposed	89,500	54.0
Ti-150-A	1020° F-48 hrs.	Unexposed	142,800	7.0
Ti-150-A	1020° F-48 hrs.	Stress Corrosion Exposed	141,400	4.0
Type 321 18-8	1020° F-48 hrs.	Unexposed	90,500	54.5
Type 321 18-8	1020° F-48 hrs.	Stress Corrosion Exposed	86,300	55.5

* Average of 2 specimens.

Corrosion and Related Problems In Sea-Water Cooling and Pipe Systems In H.M. Ships*

By I. G. SLATER,[1] L. KENWORTH[2] and R. MAY*[3]

Synopsis

A study is presented of corrosion and related problems that were encountered in sea-water cooling systems during war-time service. Details are given of the deterioration liable to occur in the component parts of the system, such as inlets, valves, gratings, pumps, trunking, condenser doors, tube-plates ferrules, condenser tubes, and piping. Impingement attack and deposit attack were the two most prominent types of corrosion encountered. It is shown that the main factors which influence these are water speeds with related eddies and turbulence, entangled air bubbles, tube obstructions, and contamination of the water. Remedial and palliative measures are discussed in relation to the corrosion-resistance of the materials and protective coatings available; the use of different alloys in the same system; modifications of design for minimizing the severity of the conditions; and the importance of maintenance routines.

Laboratory tests, and especially the jet-impingement apparatus, are shown to be of great value in indicating the probable service behaviour of materials, provided certain precautions are observed.

I—Introduction

FOR MANY YEARS, the corrosion of condenser tubes presented the biggest problem in marine cooling systems, and its importance was realized as early as 1910 when the Council of the Institute of Metals appointed a Committee to study it under the chairmanship of the late Sir Harold Carpenter. As a result of the investigation carried out under the guidance of that Committee, largely by the late Dr. G. D. Bengough and one of the authors of the present paper (R. M.), much information was collected about the causes of the various types of corrosion experienced. (Of the several papers published, attention is particularly directed to references 1 and 2.) It was found that the incidence of tube corrosion depended not only on the properties of the metal used and on those of the cooling water, but also to a remarkable extent upon the working conditions in the plant. The effects of these conditions on the tube alloys then available varied appreciably, to that, by taking advantage of the knowledge gained, it was sometimes possible to control corrosion by adjustment of working conditions to a point where one or other of the alloys could safely be used. Control, however, gradually became more difficult and the risk of failure greater with the advance in condenser efficiency required by engineering progress. Later work led to the development of more resistant alloys, and these have proved so successful for condenser tubes that unless and until changes in design bring about a marked increase in the severity of the operating conditions the condenser-tube problem may be considered to be virtually solved.

Experience in the last war, however, revealed that severe corrosion was liable to occur in other parts of cooling systems in H.M. ships, where attack had not been expected. This problem assumed serious proportions and, since it threatened to affect the serviceability of ships at a critical period, an investigation was at once started by the Admiralty with the help of the British Non-Ferrous Metals Research Association, in the hope of finding a rapid solution. After a number of inspections of H.M. ships had been carried out and experiments made with certain remedial measures, it was possible to issue to the fleet a Book of Reference to guide ships' officers, repair authorities, and designers in identifying the types of corrosion, realizing the factors responsible, and putting into effect such methods to overcome or minimize the troubles as at that time could be recommended.

The investigation was far from complete at this stage (1943), however, when its further pursuit came within the terms of reference of the then newly-formed Non-Ferrous Corrosion Sub-Committee of the Admiralty Corrosion Committee, of which all three authors of the present paper were members while this project was receiving active consideration. During this period, a considerable amount of additional experience was gained, and it is now thought that many of the observations and results accumulated in the course of the investigation would be of sufficient interest to warrant their wider circulation. The present paper has therefore been written with this object.

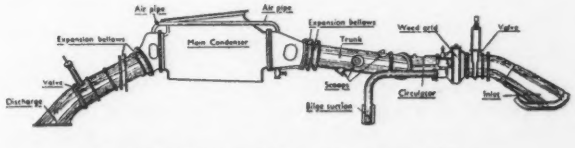

Figure 1—Diagram of the main cooling system.

★Reprinted from *J. Institute of Metals*, 77, Part 4, 309-330 (1950).

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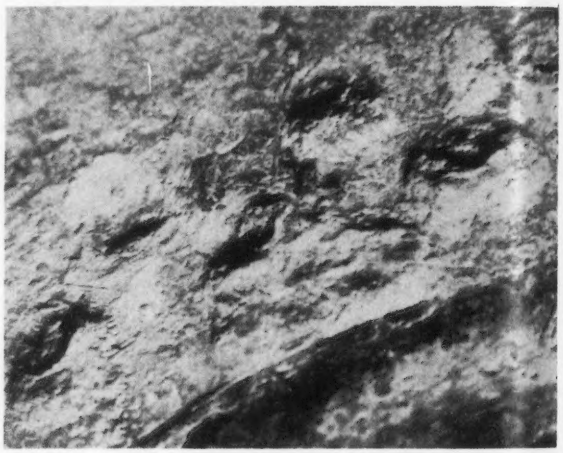
II—Corrosion in Cooling Systems

1. *Salient Features of Arrangement.*

The general arrangement of the main condenser and cooling-water systems of many naval vessels has for some time tended towards the single-pass straight-through type previously confined to destroyers (Figure 1). In this diagram a sloping inlet tube is depicted, although in some ships there may be more or less streamlined modifications of the earlier inlet box. Conditions differ from those in merchant ships largely because the whole system has to be designed for a very high maximum power output, combined with the greatest possible efficiency under the much lower power that will be used for most of the running time. To save pump power, the quantity of cooling water is varied according to requirements. Thus the average water speed in the system may at times be as low as 3 ft./sec., when mud deposits may tend to build up, and at other times as high as 12 ft./sec., when there is an ever-increasing risk of excessive local turbulence and much higher local speeds, both extremes being undesirable from the point of view of corrosion. Moreover, the water entering the system may be of varying quality according to place and circumstance. Thus, it may be brackish in estuarine waters and contaminated in and around ports; or it may contain sand or mud in shallow waters, while in-shore seaweed and other marine organisms and their decomposition products may be present in quantity, especially in some localities and at certain seasons of the year. Air bubbles are practically inevitable and require special mention because of their importance in certain types of corrosion.

Additional to the main condenser system, a number of smaller cooling systems are installed which may be fed either from branches on the main cooling-water trunking or from separate inlets. These systems may include smaller condensers, as, for example, the drain cooler, turbo-generator, air ejector and distiller condensers, and coolers of various kind such as those in the lubericating-oil and refrigerator systems. Besides the units themselves, the piping leading to and from the various units constitutes an important item, and so does the great length of piping involved in the system of fire mains throughout the ship. Each of these may show trouble of a similar nature to those of the main system, and some of them have peculiarities and problems of their own, as will be explained in the following section.

Figure 3—Steel main inlet trunking (shipbuilder's tube) looking inward, showing rust streaks indicative of turbulence in the water stream. Steel



Gun-Metal

Figure 4—Steel main inlet trunking (shipbuilder's tube) adjacent to gun-metal valve housing, showing severe wastage to rivet head. X ½.

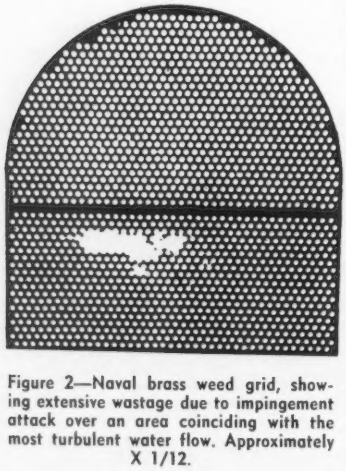


Figure 2—Naval brass weed grid, showing extensive wastage due to impingement attack over an area coinciding with the most turbulent water flow. Approximately X 1/12.

2. *Deterioration Encountered in Component Parts*

a) Shipbuilder's Inlet Tubes and Inlet Boxes. These are usually formed from steel plating, either riveted or welded, and in more recent designs are arranged to encourage scoop action and to give a reasonably smooth flow of water direct through the system with a minimum of pumping when the ship is steaming ahead. Earlier designs making use of scoop action, of which Figure 1 may be taken as an example, were less satisfactory, the flow up the large convergent inlet often being excessively turbulent. Before undocking, the inlets receive the same protective treatment with paints as does the remainder of the under-water plating, namely, one or more coats of

Figure 5—Naval brass valve spindle from fire-main system, showing impingement attack. X 1.

protective paint composition with a final coat of anti-fouling composition. In less satisfactory designs of inlet, the protective coats of paint may be eroded away rapidly, leaving bare steel exposed which may show rapid wastage and ultimate penetration by corrosion. Areas thus attacked often lie at the crown of the tube or at other points where there is a sudden change in the direction of flow, leading to impingement of rapidly moving water against the surface. Figure 3 demonstrates the effects of a rotary motion which may develop.

In addition, substantial areas of non-ferrous metals are located inboard adjacent to the steel tube, and these tend to accelerate attack of the upper end of the tube by galvanic action (see Figure 4). It is normal practice to fit zinc protector slabs on the steel immediately adjacent to the gun-metal valve casting, and there is little doubt that this lessens the tendency for galvanic attack on the steel, as long as the zinc lasts or is in metallic contact with the steel. This practice, however, is not free from the danger of mechanical damage to parts of the circulator and sometimes to the condenser ferrules in ships not fitted with a weed grid, owing to large pieces of zinc coming adrift and being carried in the water stream. Consideration has recently been given to the use of better-quality protective paints (conveniently known as high-duty compositions) on the steel tube, and to the possibilities of lining the tube with rubber or other resistant material.

b) **Valves.** These are almost invariably made of gun-metal* in Service ships and are singularly trouble-free on this account. Corrosion is sometimes encountered with the slide-operating spindle, if made of rolled naval brass (Figure 5), as this is liable to suffer dezincification, especially by contact in seawater with the more noble gun-metal.

c) **Inlet Gratings and Weed Grids.** It is usual to fit some form of grating to exclude flotsam which might damage the circulators or prevent the closing of valves. In some cases this is built up of mild-steel slats, running fore and aft, fitted over the bottom end of the inlet and flush with the outer bottom plating. Troubles encountered with this type of grating are usually associated with an insufficiently robust design, which allows vibration and so results in subsequent failure of the slats by corrosion-fatigue. The design of grating very considerably affects the degree of turbulence in the water stream, and although later designs are better in this respect, the ideal grating has yet to be designed.

In destroyers and smaller ships, a weed-grid is also fitted in an athwartships box between the inlet valve and the circulator, comprising a non-ferrous plate drilled with holes. Rolled naval brass has been commonly used for this component and very many cases of rapid deterioration have been encountered, as illustrated in Figure 2. The corrosive attack is usually of the impingement type resulting from high water speeds, excessive turbulence, and entangled air bubbles. The example shown indicates that conditions favouring impingement attack were at a maximum above and to the right of the centre and may well have been associated with a vortex motion initiated in the shipbuilder's tube as illustrated in Figure 3, a matter which is discussed in Section III. 2. Often, long strands of weed lodge across the bridge of metal between adjacent holes and give rise to a "sawing" action by their fluttering movements, producing narrow grooves resembling saw cuts. Some of these weeds can be seen in the tube-plate in Figure 14. There is not much doubt that the action is mainly due to corrosion localized by the wearing away of the protective film. Other marine debris and flotsam lodging in the grid may give rise to similar effects or to deposit attack which, it should be noted, can remain active even when the system is shut down if the deposits are not removed. Parts adjacent to the weed-grid are usually of cast gun-metal which, before it becomes covered with scale, introduces galvanic effects to the further detriment of naval brass

Figure 6—Fire-pump impeller wheel (phosphor bronze casting) with badly eroded vanes and faces showing extensive impingement attack. X ⅓.

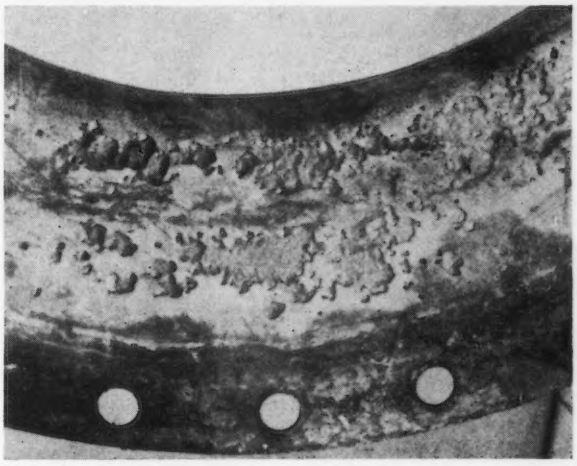


Figure 7—Portion of copper bellows piece severely affected by impingement attack at radius of leading face. X ¼.

* The chemical composition of the various alloys referred to throughout the paper will be found in Table I.

grids. Gun-metal grids which eliminate these effects and have great resistance to impingement attack have been found to give much more satisfactory service; the extra expense has been well justified where severe conditions of impingement are encountered. Another method to ensure longer life has been to paint the rolled brass grids with high-duty compositions at regular intervals, an improvisation which was found useful during the stress of war-time refits and for the purpose of economy in gun-metal. Incidentally, this procedure afforded a most excellent method for testing the relative durability of different high-duty compositions.

d) Sea-Water Pumps and Main Circulators. The pump impeller is the main sufferer in these components and is liable to impingement attack and to sand erosion and perhaps even to cavitation-erosion. A typical example of an impeller of a fire-main pump is shown in Figure 6. Phosphor bronze, which is commonly used for such impellers, normally gives reasonable service. Alternative alloys for more severe conditions are Monel metal and stainless steel, though perhaps with some risk to adjacent parts owing to the highly cathodic nature of these alloys.

e) Main Trunking. In older designs this was of cast gun-metal which is almost trouble-free, but in cases where copper had been introduced for reasons of weight-saving and ease of fabrication, substantial deterioration arose when war-time conditions of running were encountered, because of the lower inherent resistance of copper to impingement attack. Such deterioration is particularly prone to occur at areas of turbulence, as in the wake of flanged joints or of scoops where water is drawn off into auxiliary pipelines, or at bends where the direction of water flow is changed abruptly.

f) Expansion Bellows. These thin copper components, which serve to take up imperfections in alignment and to allow for a certain amount of flexure or deformation of the hull structure without the transmission of undue stresses to vital parts of the machinery, were among the first to show corrosion failures when war conditions demanded higher water speeds for long periods. The attack was again of the impingement type (see Figure 7), often accentuated by galvanic effects due to adjacent gun-metal parts, and kept active by deposit attack during stand-by periods. Protection by tinning was worse than useless, and paints invariably failed. Fitting steel wastage pieces alongside the copper bellows diminished the rate of deterioration, but was by no means a complete cure. A permanent protection was eventually found by bonding sheet rubber to the bellows, and this has now become standard practice.

g) Main Condenser Water-Boxes (Condenser Doors). Before the war these were nearly always made of gun-metal (most of the exceptions being in certain minor ships where cast iron was used), and were trouble-free except for a little highly localized attack at the air holes between the inlet and outlet sections of two-pass condensers which occurred as a result of excessive local inpingement. Consequent on metal shortages, recourse was made to doors of fabricated steel, which even more than cast iron requires adequate protection, owing to the adjacent large cathodic area of the tube plate and tubes. Attempts to find a suitable high-duty protective paint for the steel, which can be relied upon under all conditions of service to remain intact for a substantial period of time (say, 6-12 months), have so far proved abortive. One of the drawbacks to the use of paint is that local failure of the paint film at a pin-point may lead to intense pitting at the exposed area. Up to date, the complete coating of the water side of the door with rubber appears to be the most promising solution, but there is not yet enough practical experience to draw final conclusions from trials which are in progress. Some early experiments in which imperfectly bonded rubber linings became detached and stopped the flow of water are still remembered. Cast iron appears to have a lower rate of deterioration than mild steel, possibly owing to the semi-protective nature of the graphite-bearing layer which is left behind as the material undergoes progressive corrosion and graphitization. Its use, however, in ships subject to modern warfare can be a serious danger because of its inherent rigidity and poor shock-resistance.

h) Condenser Tube-Plates. The rolled naval brass tube-plates commonly employed seldom show rapid deterioration unless corrosive conditions have been exceptionally severe. Cases in point have been in two-pass condensers where the division plate had not bedded-down on the tube-plate and had provided an "easy" path for some of the water, the local high velocity and turbulence causing impingement attack (see Figure 8). The same type of attack has also been experienced in turbo-generator condensers with water passage of poor design, which have been operated for long periods at water speeds greatly in excess of requirements. The tube-plates of drain coolers sometimes suffer considerable dezincification, especially those of insufficient capacity which run consistently hot. A section of a tube-plate which has deteriorated in this way is shown in Figure 9.

Another more frequent form of attack, though generally not of very serious proportions, occurs when the system is standing idle with perhaps a few inches of water lying stagnant against the tube-plate. Consequent upon the accumulation of marine debris and the decomposition of organic matter contained in it, a form of deposit attack may be set up leading to slight overall wastage with shallow pitting in these areas. An acute form of this trouble can arise, however, as experienced in certain designs of air-ejector condensers in which, owing to imperfect circulation, a stagnant zone may exist in the second pass. The lower naval brass tube-plate then undergoes rapid dezincification under the accumulated debris, accelerated by the presence of the cathodic gun-metal water box and cupro-nickel tubes, and also by the increased temperature due to the faulty circulation. Figures 10 and 11 show an air-ejector tube-plate which has been affected in this way.

It is usual to fit steel protector slabs, spaced about two feet apart, on the inlet-end tube-plate of main condensers, and these provide useful galvanic pro-

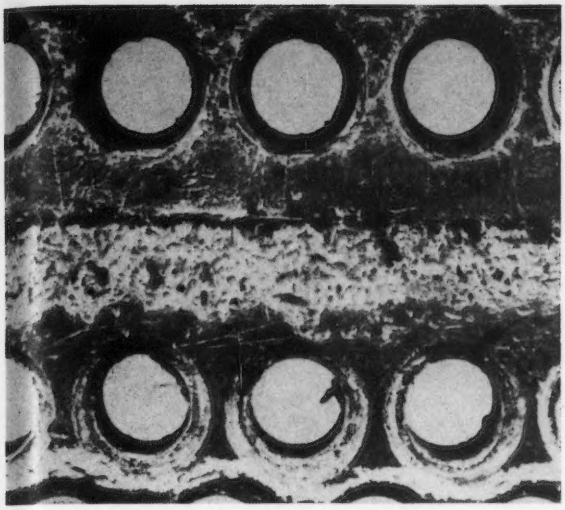
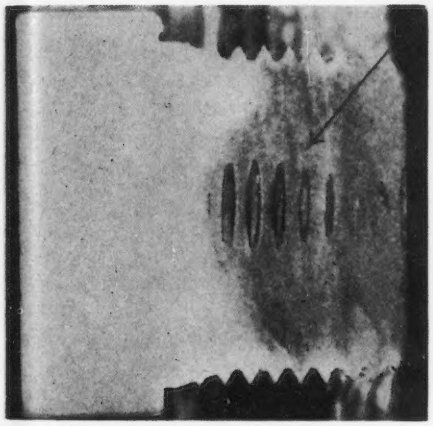


Figure 8—Impingement attack of turbo-generator 2-pass-type condenser tube plate (naval brass) immediately in way of division plate under which water has passed in a turbulent manner. X 1.



Dezincified area.

Figure 9—Cross section of drain-cooler condenser tube plate (naval brass) showing extensive dezincification. X 2.

tection to the tube-plate and ferrules when the water-boxes are of gun-metal. In addition, these protectors provide a continuous supply of iron corrosion products, some of which become incorporated in the protective film on condenser tubes and other parts, thereby materially improving their resistance to many forms of corrosive attack. In one case examined, zinc protector slabs had been fitted in error (in a new ship). These had rapidly disintegrated, leaving the brass tube-plate subjected to the full galvanic effects of the gun-metal condenser door, with the result that dezincification to a depth of up to a quarter of an inch had taken place over the whole plate.

i) **Ferrules.** Naval brass or Admiralty brass ferrules were commonly employed in pre-war years, but it soon became apparent in new designs involving higher water speeds and under the stress of wartime operation, that such ferrules were liable to rapid and severe wastage, as illustrated in Figure 12. Moreover, the deterioration tended to affect the tube ends, mainly because the corrosion products spreading from the ferrules interfered with the formation of protective films even on the most resistant condenser-tube alloys. An example is shown in Figure 13.

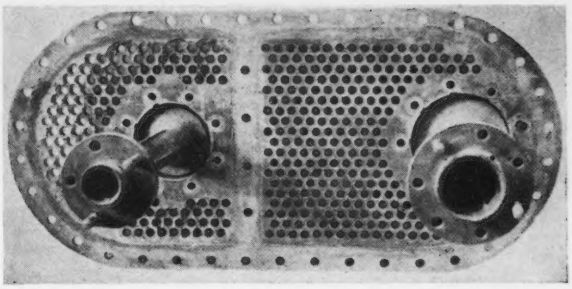


Figure 10—Lower tube-plate (naval brass) of air ejector, showing attack in second pass (left of photograph) which has taken place under an accumulation of debris resulting from faulty circulation. X 1/11.

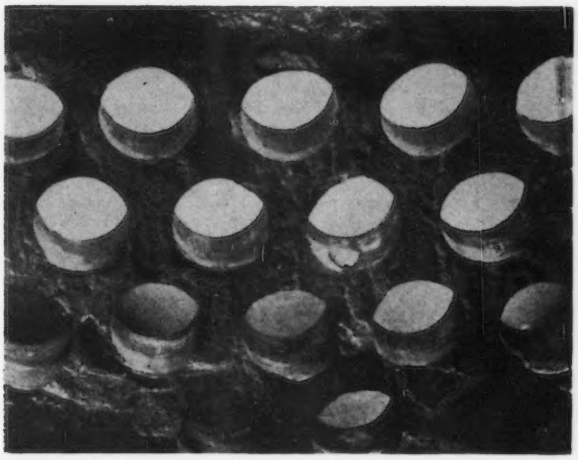


Figure 11—Enlarged view of corroded portion of tube-plate shown in Figure 10. X 1.

Occasionally, the lower rows of ferrules are more severly corroded as a result of recurring deposit attack caused by marine debris, as mentioned above. Entanglement of weed between tubes, as illustrated in Figure 14, also accelerates deterioration, mainly by abrading the naturally-formed protective layers and exposing bare metal to impingement conditions. It has often been noted that ferrules immediately behind iron protector slabs are relatively unattacked, whereas others elsewhere show substantial deterioration. Both galvanic protection and shielding from impingement may be involved in these instances.

Cupro-nickel ferrules (composition given in Table I) have now replaced brass ferrules in many important instances and have given excellent results; they will eventually become standardized in all H.M. ships. Aluminum brass ferrules, which have shown good service in merchant vessels, have also given equally satisfactory results in trials made in Service ships. Where naval brass or Admiralty brass ferrules have been fitted, coatings of high-duty protectives over the tube plate and ferrule ends provide moder-

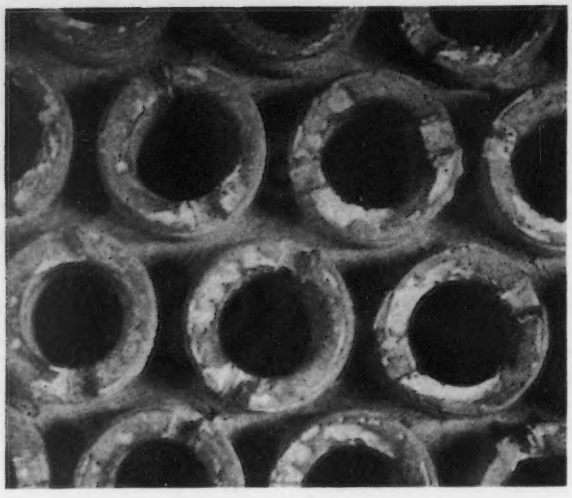


Figure 12—Typical example of impingement attack and wastage of Admiralty brass ferrules in condenser tube plate. X 1.

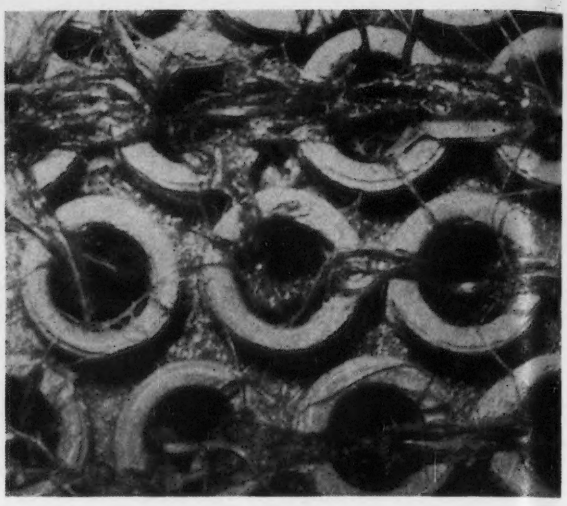


Figure 14—Section of condenser tube inlet plate as opened up, showing weed entrapped between adjacent tube ends. The strands of weed flutter in the water stream and abrade the protective film on the ferrules. X 1.

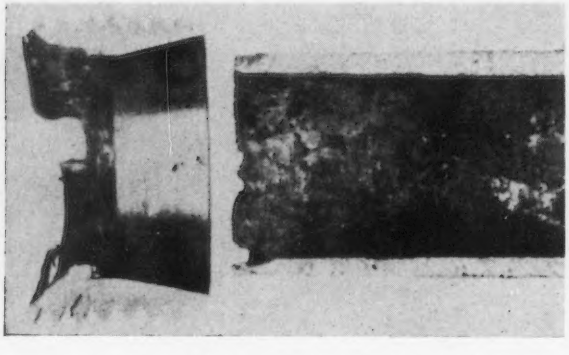


Figure 13—Section of badly corroded Admiralty brass ferrule, together with corresponding aluminum brass tube end which has been attacked in consequence. (Packing removed) X 2.

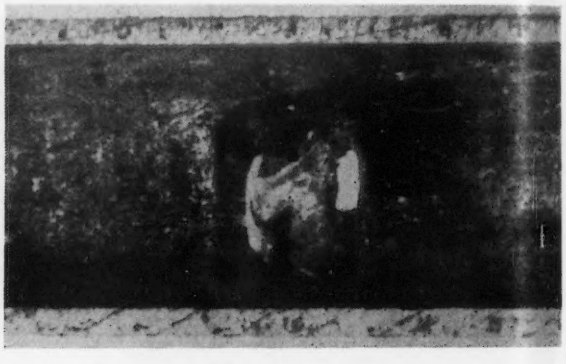


Figure 15—Perforation of an Admiralty brass condenser tube. Attack of this nature is usually associated with deposits in the tube. X 3.

ate success, but fall short of the performance offered by cupro-nickel or aluminum brass ferrules.

j) **Condenser Tubes.** In days when 70 : 30 brass or Admiralty brass were practically the only condenser-tube materials, it could be fairly said that the corrosion of condenser tubes was the most serious marine corrosion problem. Failures were mainly due to impingement attack, often set up by partial obstruction, as shown in Figure 15, or to dezincification as shown in Figure 16. The advent, between the wars, of newer alloys for condenser tubes, such as cupro-nickel, containing small amounts of iron and manganese, and aluminum brass, containing a small amount of arsenic (see Table I for compositions), has completely changed this, and tube troubles are indeed rare. Occasional failures in aluminum brass are usually due to deposit attack, assisted by decomposing organic matter and by excessive local turbulence where a foreign body has lodged (see Figure 17); or to mechanical abrasion of the protective film by a partly loose obstruction, such as a mussel, flapping in the water stream. As previously noted, cases of attack of tube ends in both alloys have been met following ferrule failures (Figure 13).

Cupro-nickel tubes have been employed more extensively than aluminum brass in naval vessels, and they are possibly more reliable under the widely varying conditions in which such vessels must operate. Aluminum brass, which in future is to be used chiefly for distillers, may show to advantage where higher temperature conditions are encountered; on the other hand, cupro-nickel is less damaged by partial obstructions and deposits of decomposing organic matter. Both alloys are about equally resistant to impingement attack under the conditions of flow at present in use. Aluminum brass possesses better thermal conductivity properties than cupro-nickel, but the significance of this difference in a condenser is still being investigated.

k) **Auxiliary Piping.** Copper piping used for fire mains and for supplying salt water to auxiliary cooling systems may show wastage mainly by impingement attack, typical instances being given in Figure 18 and 19. As in the case of other copper components, the attack is mainly associated with disturbances of flow, which in this case are particularly numerous because of the many bends, valves, and connections. To make matters worse, many of the pipes are too

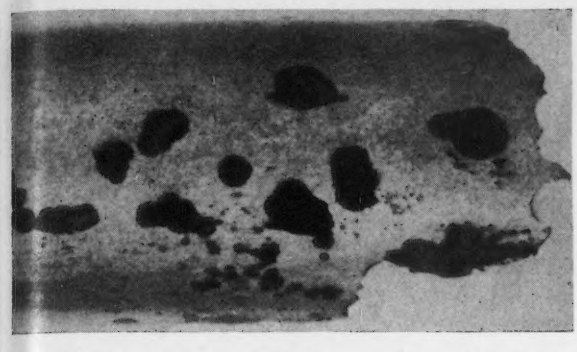
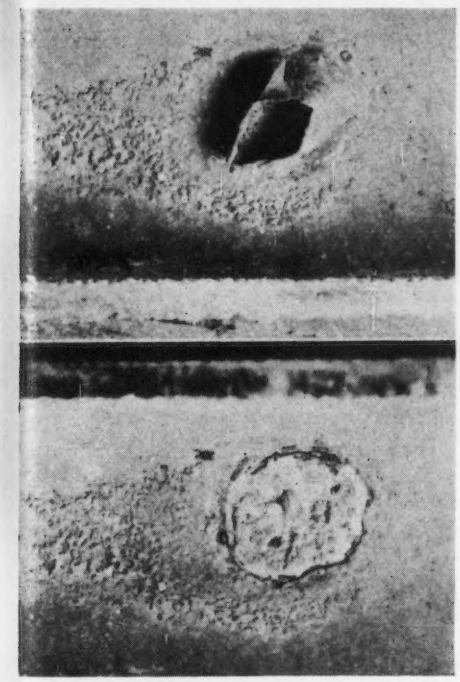


Figure 16—External surfaces of 70:30 brass condenser tube, showing severe dezincification which has penetrated the tube wall. X 3.



(a)

(b)

Figure 17—Deposit attacks in an aluminum brass condenser tube caused by a large barnacle. The decomposition products from the dead barnacle have attacked the protective film, whilst the shell itself has given rise to deposit attack and has also set up local turbulence in the water stream. X 3. (a) dead barnacle in position. (b) barnacle removed, showing attack beneath.

small and inaccessible for the application of protective compositions at regular intervals of time. Moreover, in some of the pipes the conditions may be almost stagnant for long periods, during which fouling organisms may develop to an astonishing degree and by their eventual decomposition liberate various harmful sulphur compounds into the water. During stagnant periods such compounds readily encourage pitting or larger areas of corrosion, which are then subjected to the scouring action of the turbulent water, thereby giving a particularly virulent attack.

Methods for jointing copper piping by brazing or welding merit careful thought from the corrosion point of view when the jointing alloy is exposed to sea-water. A case in point is illustrated in Figure 20, where two lengths of piping were brazed with 60:40

←——— Direction of water flow.

Figure 18—Typical impingement attack in a copper pipe, showing characteristic "horse-shoe" form of pits. X 1.

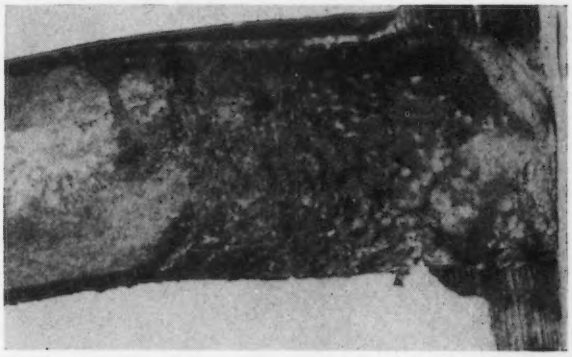


Figure 19—Copper pipe, showing extensive wastage by impingement attack immediately adjacent to the flanged end, where the water flow has been more turbulent. X 1.

brass which crumbled away as a result of severe dezincification. Failure would have been delayed considerably by making the joints with a large overlap, so that the dezincification would have had to penetrate along a film of the brazing alloy before leakage or serious weakening of the joint occurred. The use of tin-free copper-zinc brazing alloys is, however, to be deprecated; the aim should be to secure a brazing alloy in the actual joint containing not less than 60 percent copper with 1 percent tin. Alternatively, silver solders to B.S. Specification 206, Grade B (typical composition: silver 50, cadmium 20, copper 15, zinc 15 percent) or Grade C (typical composition: silver 43, copper 37, zinc 20 percent) have given extremely satisfactory results.

The care with which the joints are made is also of importance. Many failures have occurred in piping close to joints as a result of adjacent ends of piping not being correctly butted and consequently setting up severe local turbulence.

Galvanized mild steel has been used in some ships for fire mains, but not with much success. The zinc coating is fairly rapidly removed in fast-moving sea-water, after which penetration of the piping soon occurs.

In certain high-class merchant-ship practice aluminum brass has been employed for piping, but up to the present it has not been used for this purpose in H.M. ships.

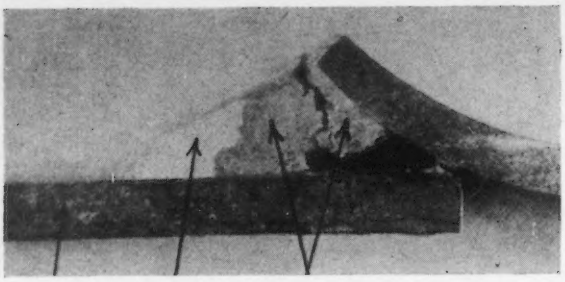


Figure 20—Section of flame-welded joint in a copper fire main. The filler metal (60:40 brass) has suffered severe dezincification. X 3.

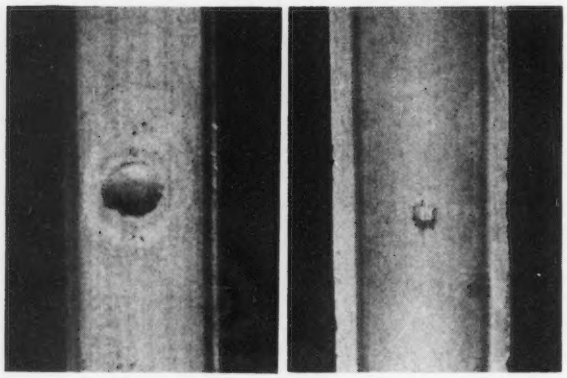


Figure 21—Portions of jet-test specimens, showing condition of surface opposite the jet after 28 days' test at a water speed of 17 ft./sec. with 3 percent entangled air. X 2. (a) Admiralty brass, deeply pitted. (b) 70:30 cupro-nickel containing manganese and iron, slightly pitted.

III.—Practical Aspects and Remedial Measures.

It might be said immediately that there were two forthright solutions to the problem: either to use an alloy such as cupro-nickel for the whole system, or to modify the operating conditions and design to minimize the harmful forms of turbulence and aeration of the moving water so that less-resistant materials might be safely used.

The questions of availability of materials in time of war as well as cost enter strongly into the picture as regards the first of these, whilst modifications of operating conditions and design are matters for much more extensive thought and investigation. Fabrication problems are formidable enough with existing materials, and nearly all piping has to be bent to the intricacies of the layout. Many added complications are inseparable from the vital requirement that replacements or repairs must be possible immediately, wherever the ship happens to be.

Design aspects involve considerations of weight, space, and efficiency, as well as factors that are significant in reducing liability to attack. The latter can be listed conveniently for discussion as follows:

(1) Relative corrosion-resistance of available materials.

(2) Conditions of water movement and aeration.

(3) Miscellaneous details of design which affect corrosion.

1. *Relative Corrosion-Resistance of Materials.*

The three most prominent types of corrosion deterioration encountered in sea-water cooling systems are impingement attack, pitting, and deposit attack, and a rough guide to the relative resistance of various materials is given in Table I.

The water speeds given in Table I in relation to liability to impingement attack refer to the ordinary conditions of turbulence and aeration associated with most of the present designs, and it is necessary to consider lower speeds if these conditions are intensified at any point or if there is an unfavorable combination of different metals in contact at points of impingement. Thus, for Admiralty brass under the least favorable conditions involving excessive aeration, impingement attack will occur at water speeds as low as 6 ft./sec. On the other hand, higher average speeds might be safe in some cases if special precautions could be taken to eliminate rotation of the water stream as well as the local concentration of air bubbles, as discussed in the following section. A further significant point is the relative "newness" of the system. If good natural protective films have formed upon the metal surfaces, e.g. during favorable conditions in early service, the resistance to impingement attack is substantially greater, and it has been found that troubles are usually more evident during the early history of a ship and tend to die away in the course of time for this reason. It would appear that differences in the rates of protective-film formation on the various materials can give rise to critical periods in which one reaches a highly cathodic stage to the detriment of an adjacent material on which the film is not yet fully protective. In due course the main cathodic areas, such as a gunmetal condenser door, tend to become passivated or

TABLE I—Approximate Resistance of Materials to Impingement, Pitting, and Deposit Attack as Observed in Service

MATERIAL	Average Water Speed (ft./sec.) at Which Risk of Impingement Attack Generally Arises Under Practical Conditions	Resistance to Pitting	Resistance to Deposit Attack
Tough-Pitch Copper	6	Moderate*	Moderate
Deoxidized Copper	7	Moderate	Moderate
Arsenical Copper (0·3-0·5% As)			
Admiralty Brass (70% Cu, 29% Zn, 1% Sn)	10	Moderate	Moderate
Naval Brass (60% Cu, 39% Zn, 1% Sn)			
Cupro-Nickel (30% Ni, 0·5–1·5% Mn, 0·4–1% Fe)	15	Good†	Good†‡
Aluminum Brass (76% Cu, 22% Zn, 2% Al, with 0·01–0·05% As)	15	Good/moderate§	Very Good/moderate§
Cast Gun-Metal (B.S.S. 382: 88% Cu, 10% Sn, 2% Zn; or B.S.S. 1023: 86% Cu, 7% Sn, 5% Zn, 2% Pb)	20	Very good	Very good
Phospor Bronze || (90% Cu, 10% Sn, 0·3% P)	Approaching 20	....	....
Rubber	Immune	Immune	Immune

* Though attack may be considerable it tends to be widespread and shallow.

† Attack, if any is usually widespread and shallow.

‡ Cupro-nickel is less affected by decaying organic matter than other materials.

§ Aluminum brass may be badly affected by decaying organic matter.

\|\| The authors have had but limited experience of this material in cooling systems.

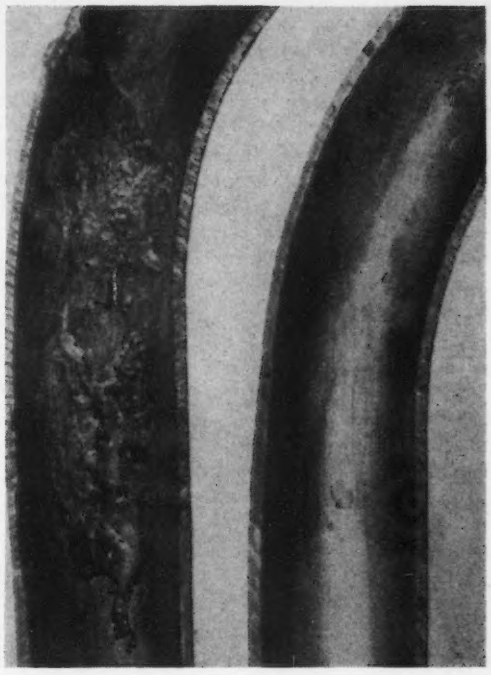
even insulated by scale formation. A film of calcium carbonate from the sea-water—the characteristic "cathodic chalking"—is perhaps the most common, but films containing calcium sulfate and corrosion products such as iron rust from protector slabs are important.

2. Conditions of Water Movement and Aeration.

i) **Water Speed.** It must be emphasized that, in general, impingement attack is not caused directly by a high average water speed but by much higher local speeds often assisted by local concentration of entangled air bubbles. Both of these factors depend on various forms of additional turbulence superimposed on that normally associated with flow at the average speed. Unfortunately, in many cooling systems such excess turbulence is present, varying directly with the average speed, with which therefore impingement attack has an indirect connection. However, if by accident or design excess turbulence is small, both average speed and aeration can be higher without impingement attack taking place.

ii) **Rotation of the Water Stream.** The most harmful forms of excess turbulence can arise if a rotational motion is imparted to the main water stream so that large vortices develop. These can produce impingement conditions of great severity by the high local speed brought about by the rapid rotation at the centre of the vortex and also by causing the small air bubbles present in the water to collect together and coalesce by centrifugal action. Such rotation is easily imparted by unsatisfactory design of the inlet system, as previously mentioned. Unsuitable scoops in the trunking or certain designs of bends can occasion similar rotation on a smaller scale. If undisturbed, the rotational motion can pass through long lengths of pipe without causing trouble, but a sudden change of section, an abrupt bend, a partly-closed valve, or even a projecting gasket, can cause the rotation to break down and release the stored energy together with the air concentrated at the centre. This gives a local onset of excessive turbulence often resulting in severe impingement attack. Antiquated designs and water-boxes which cause rotation over the face of the tubeplate are no longer fitted to main condensers, but may still be found in a few auxiliary condensers.

iii) **Eddies and Turbulence.** Local disturbance of flow tends to destroy the stability of the boundary layer and give intermittent impingement or "scrubbing" action at certain areas, which may show corrosive effects, particularly if the metal is copper, and if air bubbles are also present. Smoothness of contour is all-important in this respect, as is shown by the undoubted success of bell-mouthed ferrules; and every effort should therefore be made to ensure that joints butt accurately and concentrically and that gaskets do not project. Scoops can also give rise to troubles of the same kind, and the best practical solution is to avoid their use as far as possible or at least to restrict their size. The large number of valves fitted in auxiliary piping presents a difficult problem, because many of them are used to control flow and are as a rule only partly open. The result is that



Copper BNF copper-nickel-iron Alloy

Figure 22—Sectioned pipes, showing condition after carrying sea water at 16 ft./sec. with 2 percent entangled air for three months in experimental apparatus. X 1.

piping on the discharge side of the valve may be subject to varying degrees of excess turbulence, which calls for a far more resistant material than copper. For the worst cases, the design of valves to incorporate some form of energy-absorbing grid on the downstream side might be worth considering. A scheme at present much used is to fit a replaceable length of thick steel pipe, and renew this as often as required. Division plates in two-pass condensers must be fitted properly, using a rubber joint to ensure a tight fit on to the tubeplate. Where the division plate is fitted horizontally, air-escape holes should be provided to avoid trapping air under the plate, but they should be so placed that the stream of water and air passing through them does not impinge on the tube-plate or ferrules.

iv) **Tube Obstructions.** Partial obstructions in tubes are another potent cause of excessive local impingement. The effect arises when the presence of an obstruction reduces the flow through a tube to a fraction of the normal amount, so that the tube friction becomes small and nearly the whole pressure drop is available to drive water past the obstruction. In a cooler with long tubes it is easily possible with a nominal water-speed of 10 ft./sec. for a local speed of 30 ft./sec. to occur at an obstruction, with most unfavorable results. If the obstruction contains decomposing organic matter, even the most resistant tube alloys might well fail. In some ways the danger of partial obstructions is one of the chief factors which limits the use of higher water-speeds, so that the design of weed-grids or strainers is a matter worthy of considerable thought.

v) Entangled Air Bubbles. It is safe to assume that even under normal running, the water passing through a cooling system will always contain air bubbles from the turbulent layer on the ship's hull. The complete removal of this air would reduce but not eliminate impingement attack in the case of copper, which at the present level of water speeds would still be liable to attack at points of local impingement. Admiralty brass and naval brass would benefit to a much greater extent, laboratory tests indicating that in the complete absence of air bubbles the most violent impingement at about 12 ft./sec. has little effect on these materials. However, this approach to the problem is mainly of academic interest because of the very small quantity of air necessary to maintain impingement attack of these susceptible alloys. About 1 percent by volume is sufficient, and in practice much less can produce severe local attack if the bubbles are collected together by rotatory motions as previously described.

Although there is little hope of achieving complete absence of air bubbles, there is much to be gained by reducing the amount in every possible way and by ensuring that the remainder are kept uniformly disseminated in the water. In order to deal with large gulps of air which might enter the system, air-escape pipes are essential at the top of the water-boxes, particularly at the inlet end; it is sometimes useful to lead these over to the outlet end to ensure a continuous action and freedom from overflow, the pipe being made large enough to pass any object which can get through the weed-grid. It must be realized, however, that the proportion of air which separates out so that it can be carried away by the air-escape pipes is small compared with that which remains entangled in the water; the time available for a bubble to separate out instead of making its small contribution to the total of damage is only 2 or 3 sec. The location of sea-water inlets in the ship's hull can have a large effect on the entry of air bubbles, but other considerations usually decide where the inlets are actually placed. It is not uncommon to find auxiliary inlets immediately below the bilge keels, which is almost the worst possible location as regards entangled air bubbles. Even some main inlets are poorly placed in this respect.

3. *Details of Design Affecting Corrosion.*

i) Steel Protectors. The value of steel protectors fitted to the tube-plate is unquestioned; they should be as large as possible and spaced with considerable care to ensure a proper distribution of the protective action with a minimum disturbance of flow. To avoid eddies and turbulence over the tubeplates and ferrules, the protectors should be placed end-on to the water stream and as much use as possible should be made of parts of the tubeplate bare of tubes, e.g. in way of the steam lanes. To ensure good metallic contact, they should be secured with a heavy brass nut, washer, and bolt.

(ii) Accessibility. Successful maintenance depends in great measure on making water-boxes accessible by means of well-sited manhole doors clear of a mass of adjacent pipe-work and fittings. A hand-hole door is essential at the lowest point to ensure complete drainage and to enable all sludge and foreign matter to be swilled away. Regular and systematic hosing down is essential to remove all debris effectively, particularly dead fish, weed, slime, and mud, which on decomposition can give rise to significant attack which is often most active when the condenser is not working.

IV.—Value of Laboratory Tests in Indicating Service Behavior.

It will be noted from the foregoing survey that most of the available metals and alloys are not regarded as perfect; the majority have their weaker points and tend to undergo some corrosion of one type or another, if the specific factors or conditions to which the material is sensitive make their appearance in the corrosive environment. This tendency has to be considered along with the better properties of each material. Of such properties, a natural protective film which only breaks down slowly even under the worst conditions and quickly forms again when these have passed is perhaps the most valuable in practice and is more likely of attainment than is complete resistance.

The elimination of the less satisfactory materials either by laboratory, semi-scale, or service trials is relatively simple. In the case of the more resistant materials, however, it is essential to realize that the specific factors which may cause their failure are so elusive that they may arise only in a small minority of cooling-water systems and may then be of intermittent occurrence depending on the precise sequence of operating conditions. For these reasons it is essential that service trials should be carried out in an adequate number of systems, in order to ensure an acceptable probability that some of them will involve potentially damaging conditions.

1. *Simulation of Service Conditions.*

As regards laboratory tests, present knowledge now permits their use not only for preliminary sorting but also for simulating a number of the rarer and more damaging types of corrosive attack. In this manner much time and effort can be saved before embarking upon expensive field trials. Unfortunately, some factors which may be responsible for practical corrosion troubles have not yet yielded to laboratory reproduction with certainty, the seasonal contamination of the water with various corrosion-accelerating agents liberated by decomposition of organic matter is a notable example.

One important reason for using laboratory tests is to save time in obtaining information on the behavior of materials. Such information would inspire little confidence, however, if tests were speeded up by introducing conditions never encountered in practice, or even by undue exaggeration of any of the known factors responsible for corrosion troubles. The principle which has now been in use for a number of years is to take the maximum rate of attack observed in practice as a standard, and to arrange test conditions so that when using the same material this rate

is approached, but not exceeded. It is also considered important that the essential factors introduced to obtain this rate of attack should be, so far as possible, the same as those which operate to produce the same type of corrosion in practice, and furthermore, that none of them should be exaggerated much beyond what would occur under the worst practical conditions. Fortunately, these limitations do not make the tests unduly slow, for although the maximum rates of attack in practice are extremely high, the conditions which produce them usually occur intermittently, whereas in the laboratory they can be maintained continuously if need be. For example, under the worst conditions of practice, i.e. when maximum attack occurs continuously, failures of 70:30 brass condenser tubes in 3 weeks or less have frequently been observed and hence this rate may be duplicated in laboratory tests without going beyond "legitimate conditions."

Some types of corrosion, of which dezincification is an example, usually progress slowly in practice because of their nature or because the factors which might cause acceleration rarely occur in the cooling systems concerned; no attempt is made to speed these up in laboratory tests for the evaluation of resistant materials for such systems. Usually it is sufficient to note the initiation of the corrosion and to estimate its rate by comparison with known check specimens tested at the same time. Other types may be slow in causing failures and their importance may be under-estimated because the factors which stimulate them are of infrequent occurrence in a particular class of cooling system. The excessive attack that can occur if conditions change and if the stimulating factors are present for a large proportion of the time, was amply demonstrated in parts of the cooling systems of naval vessels during the recent war, as described in this paper. Obviously, it is essential to know the effect of such changes on any new material, and laboratory tests with this object can be arranged so that the changes occur as required and in the proper sequence to imitate what might occur in practice.

2. Jet-Impingement Test.

In a corrosion test intended to reproduce practical conditions in a cooling system, factors that must obviously be included are water movement and the presence of entangled air bubbles, both of which play an essential part in impingement attack, which is responsible for the majority of failures in cooling systems at the present time. One way of obtaining the required combination of factors is to use the jet-impingement test,[2] in which a jet of sea-water carrying the desired amount of air in the form of bubbles impinges against samples of materials to be tested. A water-speed at the jet of 17 ft./sec. with 3 percent by volume of entangled air is mostly used. This gives a rate of attack which represents fairly closely the local maxima that can occur in a cooling system with an average water speed of about 12 ft./sec., when there is a considerable amount of turbulence and a local concentration of air bubbles due to rotating motions of the water stream. The test is run continuously for 28 days, during which the samples can be examined and compared, the depth of penetration being measured at the end of the test. The present form of jet-test equipment used in the BNFMRA laboratories is illustrated in the paper by May and Stacpoole,[3] and typical specimens after test are shown in Figure 21.

The optimum conditions for producing maximum impingement attack at the jet are critical; the main essential is that the impingement must cause the bubbles to break up into many smaller bubbles at the point of impingement. This is not difficult to ensure if the mixing of the air and water takes place under conditions of velocity and turbulence considerably less than at the jet, so that the bubbles remain large enough to be broken further when they reach the jet. Another more troublesome requirement is that there must be little air present in very fine bubbles before impingement, as these have a cushioning effect greatly reducing the intensity of impingement attack. For this reason, it is necessary in the test apparatus to remove the fine bubbles produced by impingement with a filter, so that they are not re-circulated. This action of fine bubbles, whilst noticeable with susceptible alloys such as 70:30 brass, becomes of increasing importance with resistant alloys which require the maximum intensity of impingement to test them properly.

When a test has been started, it is important that there should be no accidental stoppage or changes in the conditions, such as failure of the air-bubble supply, otherwise film formation may overtake film removal and impingement attack may stop. To ensure that mishaps of this kind do not remain undetected, at least one check specimen of a material of known susceptibility to such attack is included in each test. In the event of there being no attack of the check specimen in the first 7 days, it is still possible to obtain valuable information from the test if a scratch is made through the protective film on all the specimens at the area of maximum impingement, and this may be repeated at intervals if desired. Consistent healing of the scratch under these conditions indicates corrosion-resistance of a high order, unless, of course, the check specimen also heals, in which case it must be concluded that something has gone wrong with the test. For example, a partial obstruction which causes the bubbles to be broken up before they reach the jets can have this effect.

For this laboratory test to be of practical value, it is at present necessary to use natural sea-water, and because of its varying corrosive properties, this means that the test is not reproducible in the way usually demanded of a laboratory test. Thus, the results of any one particular test only represent practical conditions in cooling systems using that particular sea-water, so that further tests with other waters are needed before general conclusions can be drawn as to the value of an alloy. It should be remembered that variations in the corrosive properties of the water are a major factor in the practical behavior of cooling systems, and it could hardly be expected that this could be represented by a single test with one sample of water. However, there is

some prospect that before long it may be possible to shorten the testing by using a water in which any gradation of properties up to the worst that occur in practice can be assured by accurately controlled additions of the correct agents.

3. Pitting, Deposit Attack, and Galvanic Attack.

Although originally intended as a test for impingement attack, the jet test has proved a useful method of detecting pitting properties in a water due to contaminating substances and in comparing the resistance of materials to such a water. If pitting is going to take place it becomes evident in the course of a test running under the ordinary conditions. The pits may develop very close to the jet, as in the case of aluminum brass, or may be distributed over the surface under the small blisters or localized at the points of contact with the holder, as with cupro-nickel, or occur on the back of the specimens remote from the jet, as with Monel metal and stainless steel. Pitting does not emerge very definitely with ordinary brasses or copper because these materials show impingement attack in any case, and this probably eliminates any small pits that start to develop.

Useful information on the resistance of materials to deposit attack is often obtained by examining samples from the jet test at places where they have been in contact with the ebonite holders. Alloys susceptible to deposit attack often exhibit deep corrosion at these areas. However, as a rule it is advisable to supplement this information by stagnant tests in which samples are suspended horizontally in beakers of sea-water, with a small heap of clean sand on the surface of the sample. It has been found an advantage to run these tests at about 40° C, which helps deposit attack to start within a reasonable time.

It will be appreciated that, as cooling systems are often made from a number of different materials, the testing of a new alloy is not complete until its behavior when coupled with others under conditions of impingement and aeration has been checked. A good deal of information can be obtained from jet tests on coupled specimens, but it is often desirable to have more widespread and uniform impingement, and for this purpose the CRL* rotor test[4] has advantages. In this test, the samples connected together as required are all attached to the circumference of an ebonite rotor immersed in a tank of sea-water and rotated at a suitable speed.

Much useful information may be obtained by the use of small experimental condensers and by model circulating systems installed in the laboratory, and these have the advantage of providing an important link between the laboratory tests previously described and large-scale trials. The results obtained by an experimental apparatus using 1-in.-bore pipes are illustrated in Figure 22. The large quantities of sea-water required for this class of test unfortunately present a serious drawback, especially for inland laboratories, but in one of the Admiralty laboratories where this difficulty can be overcome, extended use is to be made of model circulating systems.

* Chemical Research Laboratory, Teddington.

V.—Discussion and Conclusions.

Of the various factors concerned with corrosion in sea-water cooling systems, the authors have been particularly impressed by the significance of excessive local turbulence, which may often result in damage and which is frequently caused by relatively minor design features. The use of so many different metals and alloys in the same system, especially in juxtaposition, is also a disturbing feature and probably accounts for the significantly inferior performance of systems during the early history of many ships, as a result of galvanic attack and its effect in promoting other forms of corrosion. It is fortunate that sea-water will deposit an insulating scale on the offending cathodic areas in due time and thus permit the formation of the natural protective film on the other metal surfaces. Stagnant periods when marine muds activated by decomposing organic matter settle on the metal surfaces and destroy the natural protective films, are yet another of the major problems.

The proper use of steel protectors merits particular mention, for they can do much to limit attack of immediately adjacent non-ferrous components. They can also play an important role by providing iron corrosion products which become incorporated in the protective film on condenser tubes and other parts, thereby improving resistance to attack. Protection for a limited time can be secured by suitable paint coatings, and there is an obvious need for much further research and development in this field. Sheets of natural rubber "tailored" and bonded to the metal are proving very durable, although such protective techniques are, of course, limited to the larger and more accessible parts of the system.

As regards materials for future installations, a major problem is the search for alternative and better alloys for sheet and piping which have to be shaped and bent to form. In this connection, a copper alloy containing small percentages of nickel and iron, which has been developed by the BNFMRA, has given most promising results and is now going into service to replace copper for certain piping prone to impingement attack. Its superiority to copper under these conditions is illustrated in Figure 22. As regards condenser tubes, whilst two very acceptable alloys for present operating conditions are available in cupro-nickel and aluminum brass, future designs may call for much higher water speeds and even better alloys.

As in most fields of human endeavor, good housekeeping is a corollary of success, and it is vital that strict attention should be regularly paid to maintenance routines. This is particularly so when cooling systems are laid off for either long or brief periods; simple procedures of hosing away debris and mud must not be neglected.

Laboratory testing procedures have been shown to be of very great value in aiding the selection of suitable alloys and in forecasting the probable effects of changes in design. These tests require very careful selection and control of conditions or misleading results may be obtained. Above all, it is essential to avoid either introducing conditions that are not en-

countered in practice or exaggerating any of the factors that are normally present.

In conclusion it may be stated that this investigation has demonstrated that the problems of corrosion and deterioration in sea-water cooling systems involve a large number of factors, and the basic patterns of behavior can only be approached by careful and continued observation of service performance. In particular, it should be appreciated that naval practice demands high-powered units where flexibility and irregular operating intervals are the rule; damage and deterioration are all too often initiated during these periods of either high demand or idleness. Moreover, sea-water is far from being a homogeneous or uniform fluid and a ship's cooling system has to take all that comes its way, from air bubbles to the manifest unpredictables of marine muds, flora, and fauna, and all that sinks or floats therein.

It has been shown that questions of design and layout play an important part in the problem, whilst the immensely practical considerations of cost, workability, and fabrication strongly enter the picture in the selection of desirable materials. It is clear that both designer and operator need all the information the scientist can provide if corrosion troubles are to be reduced to a minimum, and to this end the authors have endeavored to bring out the the more salient features of design which may influence performance, to suggest minor modifications which will ensure greater durability, and to indicate the characteristics and limitations of the available materials.

Acknowledgments

This paper is published with the approval of the Lords Commissioners of the Admiralty, but the responsibility for any statements of fact or opinions expressed rests solely with the authors.

The authors record their appreciation of the assistance afforded by their respective scientific colleagues and by their friends in industry. They finally wish to pay tribute to the Engineer Officers of the Royal Navy, who, in the stress of war, inspired and made possible much of the work, not only by affording facilities to see, discuss, philosophize, and experiment, but also by having faith in the scientists' prognostications.

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1. G. D. Bengough and R. May, *J. Inst. Metals*, **32**, 82 (1924).
2. R. May, *ibid.*, **40**, 141 (1928).
3. R. May and R. W. de Vere Stacpoole, *ibid.*, **77**, 331 (1950).
4. F. Wormwell, T. J. Nurse, and H. C. K. Ison, *J. Iron Steel Inst.*, **160**, 247 (1948).

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Discussions

Mercury and Its Compounds—A Corrosion Hazard. By M. H. Brown, W. W. Binger and R. H. Brown. *Corrosion*, Vol. 8, No. 5, 155-164 (1952) May.

Discussion by R. A. Davis, Chicago Bridge & Iron Co., Birmingham, Ala.:

Your paper dealt largely with the effect of mercury on corrosion of aluminum. Is there evidence of similar effects on regular carbon steels?

Authors' Reply:

We have not conducted any tests to determine the effect of mercury on the corrosion of regular carbon steels and, therefore, do not feel that we can express an opinion.

Discussion by H. Howard Bennett, Socony-Vacuum Oil Co., Inc., Paulsboro, N. J.

We experienced a failure of the tubes in an aluminum bundle in overhead condensing service on a catalytic cracking unit from mercury attack on the tubes. Is there any method of analyzing the hydrocarbon stream for mercury so that this type of failure could be predicted?

Question by R. McFarland, Hills-McCanna Co., Chicago.

What type of chemical reagents did authors use in detecting the small amounts of mercury in the corroded areas of the sample alloys? Did they use some particularly specific colorimetric reagent that gave them a satisfactory indication of mercury, and with the necessary precision?

Authors' Reply:

When organic matter is present the sample should be placed in 50 percent sulfuric acid and concentrated nitric acid added dropwise until the organic matter is completely oxidized. The mercury should then be precipitated as mercuric sulfide and analyzed spectrographically as described in the following discussion on the analytical determination of mercury on aluminum surfaces and aluminous corrosion products.

Discussion by J. R. Churchill, Chief, Analytical Division, Aluminum Research Laboratories, New Kensington, Pa.:

The analytical determination of mercury on aluminum surfaces and in aluminous corrosion products presents several special problems which obviate the application of conventional chemical and spectrographic techniques. The removal of mercury from an aluminum surface by acid or alkali attack is incomplete and uncertain, thus necessitating a mechanical method of sampling. Having obtained a satisfactory test sample, the analyst is confronted with a further problem in that conventional chemical and spectrographic methods are inadequate in sensitivity of detection. Also, there is the danger of losing mercury through volatilization if the sample or solutions of it are heated.

We have adopted a combination chemical-spectrographic test which has the desired sensitivity of detection and which eliminates the danger of losing mercury during sample preparation or testing. The sample is removed from the aluminum surface by scraping a measured area with a sharp knife. To insure removal of mercury from the surface the metal is removed to a depth of one or two thousandths of an inch. The sample of scrapings so obtained is dissolved in a mixture of hydrochloric and nitric acids. If the metal under test is not a copper-bearing alloy, approximately ten milligrams of mercury-free copper is added to the sample solution with additional nitric acid if required to effect solution of the copper. If the sample contains a significant amount of copper, sufficient copper is added to bring the total up to approximately ten milligrams. The solution is treated with hydrogen sulfide, precipitating the mercury, copper and certain other heavy metals as sulfides. The sulfide precipitate is removed by filtration using a hard-surfaced filter paper and the filter is permitted to dry at room temperature. The dried precipitate is removed mechanically from the paper and placed in the cavity of a graphite electrode. This electrode is simply a graphite rod one inch long, one-fourth inch in diameter, having a cavity three-sixteenths inch in diameter and three-sixteenths inch deep. This electrode is used as the anode of a 12 ampere direct current arc. The spectrum is recorded by means of a conventional prism or grating spectrograph using an exposure of 15 seconds. Identification and estimation are based on the intensity of Hg 2536.5. Quantitative evaluations are made by comparison with synthetic standards prepared by co-precipitating known amounts of copper and mercury. Results are usually reported as micrograms per unit area with respect to the original test specimen. The limit of detection is of the order of 0.1 microgram in the total area represented in the test.

This general method is satisfactory in a variety of applications other than surface testing, the only modifications being in the manner of obtaining the test sample and calculating the result. Sensitivity of detection is obviously impaired by the presence of major quantities of copper or other elements which form precipitates in acid solutions on treatment with hydrogen sulfide.

The Role of Oxygen in Corrosion and Cathodic Protection. By Roy V. Comeaux. *Corrosion*, Vol. 8, No. 9, 305-310 (1952) Sept.

Discussion by L. P. Sudrabin, Electro Rust-Proofing Corp., Belleville, N. J.:

The emphasis in this paper directed towards establishing the influence of oxygen upon corrosion and cathodic protection is justified. With the exception of the corrosion activity of certain micro-organisms, some of which may exist in the absence of oxygen, most corrosion observed on iron buried in soil or submerged in natural water can be attributed to the reduction of oxygen at the cathodic areas of the metal.

The dimensional concept given in this paper may be tempered by the behavior of oxygen. It has been shown that on freely corroding areas of iron exposed to oxygen, a protective film develops on which the oxygen is reduced, whereas, the adjoining areas not exposed to oxygen become active anodes. Since the electrochemical reduction of oxygen does not occur uniformly over the metal surface, it may be supposed that the dimensions of the diffusion layers, etc., vary greatly over a structure.

It may also be pointed out that the protective current requirements are nearly always greater than the current which is associated with the natural corrosion process. This suggests that the applied protective current needed to lower the pipe to soil potential to —.85 volts to a Cu SO_4 half cell may be greater than that needed to reduce the O_2 reaching the metal surface.

The importance of dissolved oxygen upon protective current requirements can be noted by using the zero potential technique Figure 1 described by Mears and Bialosky.[1] The protective current needed to produce a zero potential between the mill scale (cathode) and the scratch line (anode) is a function of the oxygen concentration in a highly resistive water, Figure 2a and a highly conductive water, Figure 2b.

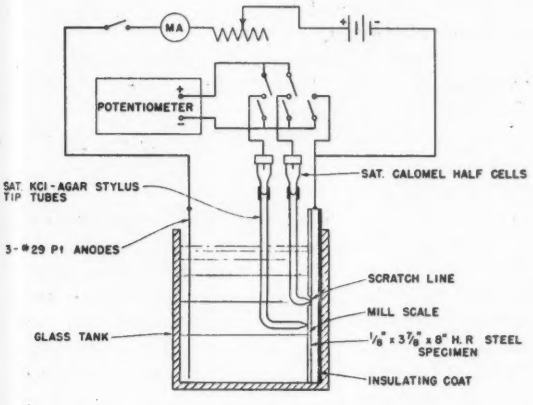

Figure 1—Zero EMF method of determining protective current

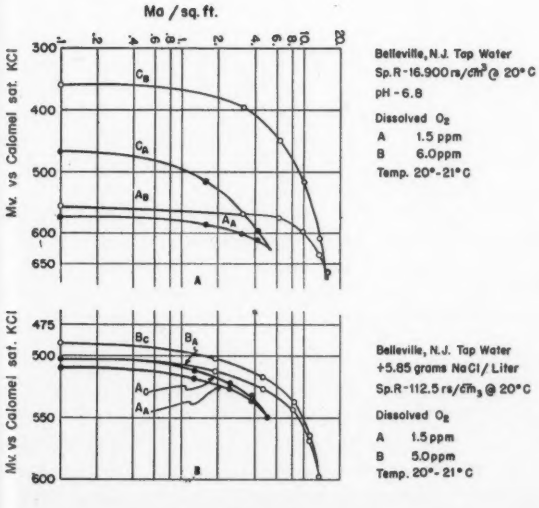

Figure 2

Reference

[1] R. B. Mears, and J. M. Bialosky. "Cathodic Protection," pages 37-46 NACE and Electrochem. Soc. (1949).

Author's Reply:

Mr. Sudrabin's assistance in emphasizing the influence of oxygen upon corrosion and cathodic protection is appreciated.

Discussion by Scott P. Ewing, Carter Oil Co., Tulsa, Okla.:

Mr. Comeaux explains in this paper the things he has observed on cathodic protection installations at the Baytown refinery in terms of fundamental physical and chemical principles. Calculations and explanations of this kind are not easy and straightforward, but they provide about the only means for obtaining a better understanding of the mechanism of soil corrosion and cathodic protection.

The observations and calculations which Mr. Comeaux has made indicate that corrosion will be prevented if enough cathodic current is applied to consume all the oxygen which reaches the metal surface by diffusion. The argument is based on the assumption that the corrosion will be stopped if the true potential of the metal surface is lowered to —0.85 volt with respect to a copper-copper sulfate electrode. The writer is in agreement with this general principle. There is also no question as to the importance of oxygen as a cathode depolarizer in the corrosion process.

It does not follow, however, that the rate of corrosion of steel in soils is proportional to the oxygen supply on the steel surface. There is an abundance of evidence which shows that the situation is exactly the opposite. This is not merely because the low wet places are usually anodic to the higher and dryer places on a pipe line. The data from the National Bureau of Standards soil corrosion investigation is sufficient to illustrate the point. On page 104 of National Bureau of Standards Circular C450 the 47 soils in the original group of test sites are arranged in order of their corrosiveness. This chart is based on *measurements* of pit depth on about 140 separate specimens at *each* test location. The four least corrosive soils

are two gravelly, sandy loams; a sandy loam; and a loam. The four most corrosive soils are muck, clay adobe, tidal marsh and peat. Obviously the gravelly, sandy loams are well aerated while in the muck and tidal marsh soils there is no oxygen at pipe depth.

Oxygen has a dual role in corrosion. It acts as a cathode depolarizer and thus tends to increase the corrosion rate. It also acts as an anode polarizer by precipitating iron ions near anodic areas and thus slowing the corrosion process. This apparently is all in accord with the Pourbaix diagram. The extreme example of this is the stainless steels where anodic areas do not exist if oxygen is present because the oxygen immediately repairs any breaks in the oxide film and the metal is kept in a passive condition. In most soils the role of oxygen as an anode polarizer more than offsets its role as a cathode depolarizer. Hadley, Starkey and Wright concluded that the *reducing* power of soils, as measured by Redox potential, "displays considerable promise whereby such (corrosive) areas may be located in the field."

It thus appears that if the oxygen supply is a measure of the corrosion rate in the soils at the Baytown refinery, this location is an exception to the general rule.

Author's Reply:

The author is indeed grateful for the thorough consideration given this paper by Dr. Ewing. In answering the specific comments, let's start with the last paragraph.

The soils at Baytown are no exception to the general rule. Admittedly, contamination by chemicals is inherent in refinery operations, but each section of the refinery should bear at least some relation to one of the 47 soils in which Bureau of Standards specimens were exposed. The difference between the refinery observations and those of the Bureau of Standards project can be explained by the fact that in a refinery several million square feet of electrically coupled ferrous surfaces are exposed to soil at various depths, and with variations of every conceivable factor. Only the variation of the moisture and the oxygen factors, however, can explain the preponderance of leaks on the bottoms of lines before protection was applied.

The data presented in Circular C-450 does not tell what would happen to the specimens in the four most corrosive soils if these were electrically connected to the specimens in the four least corrosive soils. Neither does it say what would happen to a 30-inch diameter line in a 60-inch trench in one of the least corrosive soils. Neither the Scott nor the Ewing equation takes diameter and depth of burial into account as variables in the localization of corrosion. The circular does indicate, however, that for Bessemer steel the maximum penetrations would be higher for 3-inch diameter pipe than for 1½-inch diameter pipe after 17 years. (Reference Table 37, page 76, Circular C-450.) The increase in maximum penetration varied from 10 percent to 120 percent in the four least corrosive soils. It is also stated on page 58 that a tendency was noted early in the investigation for 3-inch specimens to contain deeper pits than 1½-inch specimens. Figure 12 indicates that the pitting factor is highest in well drained soils and the discussion states that the pitting factor tends to be larger for larger specimens, although the maximum depths were higher in the more corrosive soils, which were generally of low resistance.

It is the author's contention that the larger the specimen the greater the opportunity for differential aeration. When differential aeration exists the areas "passivated" by the oxygen are cathodic to areas less accessible to oxygen. The lesser amount of oxygen approaching anodic areas is utilized oxidizing the ferrous ions at some distance from the corroding metal surface. The energy available to sustain the corrosion reaction is greater when the difference in oxygen concentration is greatest; for given steady concentrations the resultant difference in potentials between anode and cathode would result in corrosion at a rate limited by circuit resistance.

It is suggested that one of the most important variables to be considered, if not the most important, is the relation between pipe diameter and trench depth. A recent failure at Baytown was that of a 400-foot section of 15-inch steel line with the top just barely covered in well aerated, sandy soil. All leaks were on the bottom of the pipe. The bare pipe had never been protected.

Discussion by O. C. Mudd, Shell Pipe Line Corp., Houston:

This paper presents an interesting phase of problems encountered in cathodically protected bare or poorly coated underground structures.

The author is commended on the presentation of data based on fundamental chemical equations and other calculations from fundamental units.

While this role of oxygen can contribute to depolarization of cathodic surfaces there are other possible factors causing variations of current density required to maintain satisfactory cathode conditions. Some of these factors have been discussed in this article, such as variations in the rate of oxygen diffusion through soils, hydrox-ion concentration at cathode surfaces and their diffusion rate. Other factors to be considered are potential differences between points on a line due to natural concentration of chemicals or those produced by chemical migration to cathode areas allowing higher current density, hydrogen absorption by soil chemicals or by biochemical action and possible catalytic action by trace chemicals that may result in hydrogen utilization or promote corrosion with reaction potentials above those applied for protection.

Fundamental and experimental data in this paper reveal the need of considering the effects of oxygen when cathodic protection is applied but this factor should be only one of many that may contribute to variations in protection results obtained.

Author's Reply:

I appreciate Mr. Mudd's comments, as the paper as presented does not stress the fact that it is concerned only with the role of oxygen. I cannot comment on the relative importance of the differential aeration mechanism and the other possible mechanisms mentioned by Mr. Mudd. It is my opinion,

however, that in a well aerated soil the cathodic reaction is oxygen reduction to hydroxyl ions rather than hydrogen reduction followed by oxygen depolarization. On the other hand, a surface protected by a small current density in a wet season may be polarized by the hydrogen reduction reaction because the rate at which electrons reach the surface exceeds the rate of arrival of oxygen molecules. As a dry season approaches and oxygen penetration of the soil is facilitated hydrogen polarization will not be maintained when less than four nascent hydrogen atoms (one of which forms for each electron supplied) are formed for each molecule of oxygen reaching the surface. The potential then becomes less negative because the oxygen reduction reaction occurs at a less negative potential.

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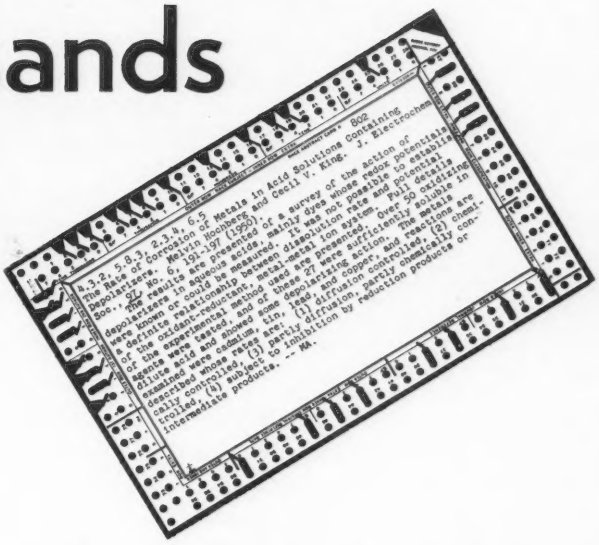
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Corrosion of Metals in Acid Solutions Containing
the Rate of Hydrogen and Cecil V. King. J. Electrochem
Depolarizers. 6: Melvin Hoohers
Soc., 97: The results are presented of a survey of the action of
depolarizers in aqueous acids on metals mainly dyes whose redox potentials
were known or could be measured. It was not possible to establish
any definite relationship between dissolution rate and full details
of the orident-reductant, metal-metal ion system. Over 50 details
of the experimental method used are presented. Over 27 were suitable
agents were tested and some of these are soluble in
dilute acids and showed depolarizing action. The metals are
described whose rates, tin, lead, and copper, and reactions chemi-
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trolled, (4) subject to partly diffusion controlled, (5) chemi-
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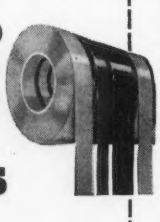

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Official Publication

NATIONAL ASSOCIATION OF CORROSION ENGINEERS

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INDEX TO CORROSION ABSTRACTS, Volume 8, 1952

Numbers in this table are those printed in the lower outer margins of the Corrosion Abstract Section, cumulative through the volume. Topical headings in the left column are those of the first and second subdivisions of the NACE Abstract Filing Index, revision of September 1952. This index may be found reproduced in full as part of the Index to Technical Material Published in Corrosion in the December, 1952 issue of Corrosion. Principal difference between this index and that published in the December, 1951 issue is the addition of designation **6.11 Design, Influence on Corrosion.** Refer to footnotes for changes in **8. Industries** not affecting validity of indexing of previous abstracts.

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* **The following designations apply to the several gorups listed under 8. INDUSTRIES:**

1. Air conditioning, architecture and building, refrigeration, sewage and water.
2. Communications, power.
3. Agriculture, beverage, dairy, fermentation, food, sugar, starch.
4. Fuel, solids; fuel, gases; petroleum refining and production, rubber, atomic energy.
5. Ceramics, glass, pulp and paper, wood products.
6. Laundry, soap and detergents, textiles.
7. Graphic arts, instruments, jewelry, photography.
8. Chemical manufacturing, distilled liquor, electroplating, leather and tanning, metal fabrication and finishing, pharmaceuticals.
9. Aircraft, automotive, pipe line, railroad, shipping.
10. Explosives, metallurgy, mining ordnance and war materials, other.

ERRATA—Volume 8 Jan.—Dec., 1952 Inclusive

Errata included here are designed to be clipped and pasted over the errors.

March, 1952 Contents Page correction:
(Changing the page number from 111 to 112c)

Discussion—Literature Survey on Corrosion in Neutral Uncerated Oil Well Brines
By F. A. Prange; Reply by Harry R. Copson **112c**

●

PAGES FOLLOWING PAGE 112:
Correct the page numbers as follows:

Change 113 to 112a.
Change 114 to 112b.
Change 111 to 112c.
Change 112 to 112d.

●

Gasoline Resistant Tank Coatings. *Corrosion*, 8, No. 6, 195-204 (1952) June.
Page 195. Delete from the abstract the fourth paragraph beginning: "A discussion of the problems of coating . . ."

Page 197, substitute the paragraphs below for those in column one beginning with the words: "Figure 6 . . ."

The polysulfide-type material was applied at an average thickness of 13.1 mils (52 measurements taken; minimum reading, 8 mils; maximum reading, 19 mils). This involved an initial brush coat, followed by three spray coats. The vinyl-type material was applied at an average thickness of 7.4 mils (53 measurements taken; minimum reading, 5 mils; maximum reading, 12 mils). This involved an initial brush coat, followed by five spray coats. The Saran-type material was applied at an average thickness of 7.1 mils (35 measurements taken; minimum reading, 5 mils; maximum reading, 10 mils). This required five brush coats.

Figure 6 shows an area of the tank after coating with the Polysulfide-type material. Figure 7 shows the same area after being in service for 19 months.

Transposing the two paragraphs involved.

(Continued in Next Column)

Page 201, table at bottom of page, under headings, "Barrels, 50,000" in rightmost column, second item from bottom, change to read:

Two-25,000

Changing the figure 2 to the word "Two."

Page 202, left column, fourth paragraph beginning: "a. Using a Type . . .," substitute the following two lines for the second and third lines of the paragraph:

ing a spray gun with a number 64 air cap and AV-15-D fluid tip. Pressure tank should be oper-

Changing the number 62 to 64 and the designation AV-15-AC-N to AV-15-D.

●

August issue, change folios as indicated:
Change page number 293 to

292a

Change page number 294 to

292b

●

In the September, 1952 issue, Contents Page, add the following just above the heading "NACE REGIONAL AND SECTIONAL NEWS:"

An Improved Electrolysis Control Switch by V. B. Pike
Discussion by H. G. Burd **322**
Reply by V. P. Pike, Page 323.

Errata, Vol. 8, Continued

Stress Corrosion Cracking of Steels Under Sulfide Conditions. By C. N. Bowers, W. J. McGuire and A. E. Wiehe. October, Page 339:

Substitute the following figures with cutlines for figures and cutlines of same numbers:

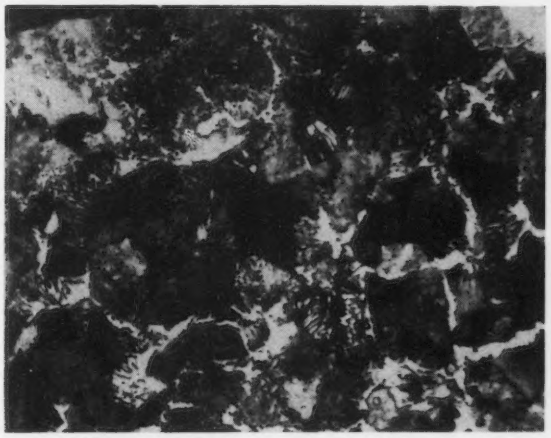


Figure 9—Structure of substitute Grade N-80 steel. No Martensite is present. Nital + picral etch, X 1000.

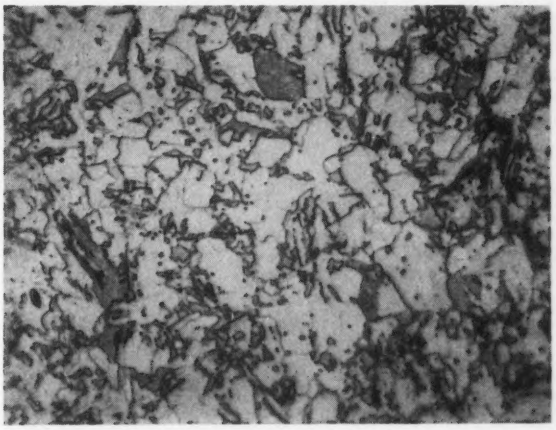


Figure 10—Structure of 5 percent nickel steel showing scattered areas of martensite. Nital + picral etch, X 1000.

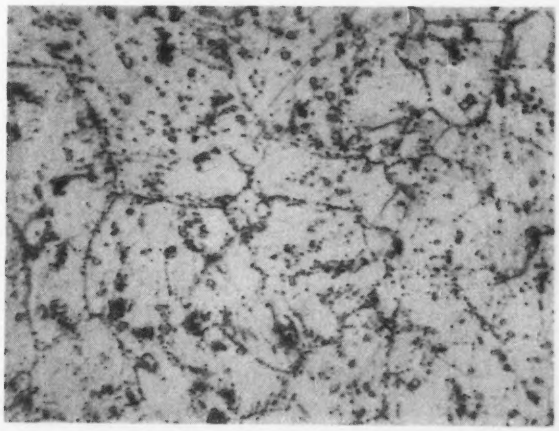


Figure 11—Fully tempered low carbon martensite with spheroidized carbides in 9% chromium—1% molybdenum steel. Nital + picral etch, X 1000.

Early Iron Box Car's 63 Years' Service Included Civil War Combat Duty *

WHEN GEN. J. B. HOOD shoved an old iron boxcar into Etowah Creek after having taken it as far as he could in the mad dash his Confederate forces made toward Nashville in the closing days of the Civil War, he thought it was the last to be seen of the car. The car, after having served the Union forces in various capacities, including duty as an armored scout car and headquarters for Union Gen. Joseph Hooker while the "Battle Above the Clouds" at Lockout Mountain, Tennessee was planned, was liberally dented by Confederate balls fired at the car during its operations around Chattanooga.

Built by the New York Central Railroad in 1859, the car was taken over by the United States Military Railroad two years later, at the outbreak of the Civil War. She was used first between Louisville and Bowling Green, Ky. then, in February, 1862, she was taken to Nashville by Union Gen. D. C. Buell, where she created a sensation, local citizens flocking to the railroad yards to see the "iron car" the Yankees had brought with them.

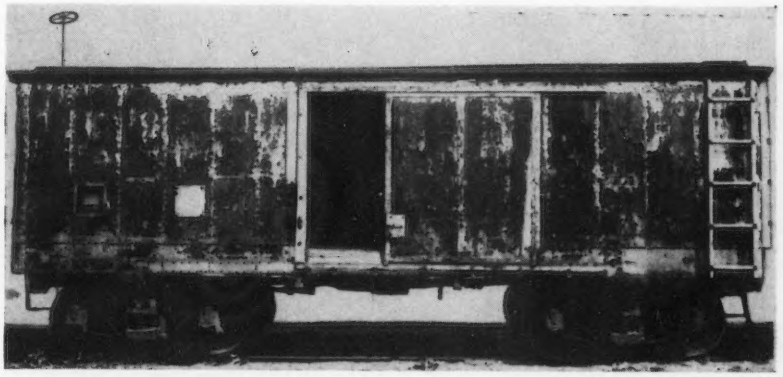
After hard service by the Union forces, including use by General William T. Sherman to carry ammunition for his army on its "March to the Sea," she was abandoned at Kennesaw Mountain by Sherman.

There she was picked up by Hood, who later dumped her in Etowah Creek along with several other wooden boxcars.

In 1865, after the end of the Civil War, the car was fished out of the river by the N. C. and St. L. railroad, and put into freight service as No. 300. When Commodore Vanderbilt heard of this, the New York Central lodged a claim against the N. C. & St. L., which was not settled until long afterward when the latter road paid the United States Military Railroad a million dollars for all rolling stock and equipment left from the war period.

The car then was used to carry baggage between Nashville and Chattanooga, and in 1916 was put in storage at the Nashville shops. In the summer of 1920, after another period of federal operation of the railroads, she was again pressed into service to haul cement and supplies at Hollow Rock Junction, Tenn. where on a siding at 2 a.m. February 15, 1922 a cargo of dynamite she was carrying exploded and wrecked her completely.

Thus ended the colorful 63 year career of this old car. The original trucks on the car were removed in 1914 after having traveled uncounted thousands of miles since 1859.



Shown is the old iron car as she appeared May 15, 1920, just before she was repainted and put back in service on the N. C. and St. L. Trucks on the car were changed in 1914. One of the bolster truss rod plates included the following cast inscription: M. B. Davidson, Maker, Albany, N. Y.

•

Nashville, Chattanooga & St. Louis Railway
Mechanical Department
Specification for Old Powder Car— N. C. & St. L. Ry. No. 90180

Length over end, outside.....28'-0"
Truck centers .....18'-6"
Side door
opening ..... 5'-3" wide by 5'-9" high
Clear height, inside..... 6'-0"
Width, inside ..... 8'-0"
Width, outside ..... 8'-7"
Length between coupler centers..31'-0"

Underframe

The underframe consists of four 6-inch I beams equally spaced. Two 1 ¼-inch truss rods. The side sill is an extension of the side plate with two 2-inch x 2-inch ¼-inch angles spaced 6 inches back to back, the top one serving as a connection for the oak floor. The oak flooring is bolted to each I-beam with carriage bolts.

Side and Roof Frame

There are sixteen 1¾-inch x 1¾-inch x 5/16-inch angles on each side extending from the bottom of one side up under the roof to the bottom of the other side. These angles are spliced on center line of roof. The side plate is a 2½-inch x 2½-inch x 5 16-inch angle placed on outside of post angles where they bend to go under roof. The side and roof sheets are riveted to each post angle and side plate angle with flat head rivets. Side and roof sheets ⅛-inch thick.

End Frame

There are six 1¾-inch x 1¾-inch x 5/16-inch angles on each end. End plate ⅛-inch thick riveted to each angle. The angles and end plate extend to bottom of the 6-inch I-beam under frame. The 6-inch I-beam is tied at each end with ⅛-inch plate, 18 inches wide, placed on the bottom of beams. Dead wood block 6-inch oak.

Body Bolster

The body bolsters are 5 x 12 oak with two 1¼-inch truss rods.

Side Door

Side door made of two ⅛-inch plates with bottom slide shoes. Door bound by ¼-inch x 2-inch flat iron bars.

Trucks

The original trucks of this car were removed about seven years ago.

On one of the bolster truss red plates is this cast inscription: M. B. Davidson, maker, Albany, N. Y. Date built, about 1860.

Office of Supt. of Machy.
N. C. & St. L. Ry.
Nashville, Tenn.
May 27, 1921.

★Based on information supplied by F. K. Mitchell, New York Central System, New York.

NACE News

Canadians File Petition for New Region

Jacksonville, Florida Petitions for Section In South East Region

A petition has been filed with H. C. Van Nouhuys, of South East Region NACE, for the formation of a new section of the association at Jacksonville, Fla. Henry T. Rudolf, of Atlantic Coatings Co., Inc., Jacksonville, chairman pro-tem, forwarded the petition signed by fifteen members.

Mr. Rudolf said also the pro tempore secretary is H. E. Alexander, Dozier & Gay Paint Company, Jacksonville.

Limits of the section geographically have been suggested as extending southerly to an east-west line across the bottom of Lake Okeechobee, and northward to include the pulp and paper industries in lower Georgia, Eastern South Carolina, Southeastern Alabama. Principal local objective is to provide a forum for the pulp and paper industry which has some 18 plants near Jacksonville which spend about $7.5 million yearly on paint and application, Mr. Rudolf said.

Assuming approval of a section being organized at San Diego Calif., the Jacksonville section will be the twenty-seventh section in NACE.

J. M. Pearson

Memorial services were held at Swarthmore Presbyterian Church, Swarthmore, Pa., Wednesday, November 19, for J. M. Pearson, director of Sun Oil Company's Research and Development Department at Sun Physical Laboratory, Newtown Square, Pa., who died November 16. He had suffered a heart attack earlier. Dr. Pearson, formerly a director of NACE, and long active in the organization's management and technical work, was recipient of the 1948 Speller Award. In September he was one of the lecturers at the Washington University, St. Louis short course on corrosion and was in wide demand as a lecturer because of his knowledge of corrosion processes.

He held a Ph.D. from California Institute of Technology, and worked in numerous capacities for Sun Oil Company prior to being made director of the physical division laboratory. He was a member of American Petroleum Institute, American Physical Society, Electrochemical Society, Franklin Institute and a fellow of the American Association for the Advancement of Science.

NACE MEETINGS CALENDAR

1952

Dec.

3—Sabine-Neches Section. Orange, Texas.

4—Pittsburgh Section. Inhibited Compounds and Their Importance in Corrosion Prevention by Raymond A. Shoan, Dearborn Chemical Co., Chicago.

8—North Texas Section. Metallurgy by Herbert M. Cooley, Bethlehem Steel Co., Tulsa.

9—Houston Section.

10—Boston Section. Manufacturing and Application of Titanium Metal, by H. P. Meissner. Beaconsfield Hotel, Brookline, Mass.

12—Philadelphia Section. Recent Trends in Stainless Steels and Other High Alloys by Walter A. Puce, Duriron Co. Poor Richard Club.

16—Cleveland Section. The Application of Corrosion Preventives by Army Ordnance by D. W. Wright, Cleveland Ordnance District.

1953

Jan.

5—North Texas Section.

13—Cleveland Section. Joint meeting with Cleveland Electro-chemical Society. Recent Developments in Corrosion Laboratory Techniques.

13—Houston Section. Condenser Tube Alloys by A. W. Tracy.

20—Chicago Section. Stainless Steel Corrosion Failures by Barclay Morrison, Carpenter Steel Co.

27—Southwestern Ohio. Inco film "Corrosion in Action." Discussion by Roy O. McDuffie, University of Cincinnati.

Boston Meeting Is Held

Greater Boston Section will hold a dinner meeting December 10 at Beaconsfield Hotel, Brookline, Mass. A social hour will be held from 5:30 to 6:30 p.m. and dinner will begin at 6:30, followed by the technical program.

H. P. Meissner will speak on Manufacturing and Application of Titanium Metal.

Southwestern Ohio Section

Southwestern Ohio Section will send no notices in advance of meetings, Lewis M. Lederer, secretary, announced October 16. Members were requested to keep available the schedule for the year, notifying Mr. Lederer five days in advance of each meeting concerning reservations.

Average attendance of 60 persons at meetings last year was reported for the section.

Hamilton, Ontario Is Likely Site of First Dominion Section

A petition has been filed with the National Association of Corrosion Engineers' board of directors for formation of a Canadian Region of the Association. The approximately 80 members of NACE in the Dominion have been working toward this end for the past several months.

There is indication the first section of the Canadian Region may be formed at Hamilton, Ontario.

The board of directors will consider the implications involved in the formation of an NACE subdivision outside the political boundaries of the United States, and other matters involved in the proposed new subdivision.

Pittsburgh Section Holds Round Table Discussion On Corrosion Testing

A round table discussion on corrosion testing was the feature of the November 6 meeting of Pittsburgh Section at the conference room, Mellon Institute.

Other meetings scheduled by the section are:

December 4—Inhibited Compounds and Their Importance in Corrosion Prevention by Raymond A. Shoan, Dearborn Chemical Co., Chicago.

February 5—Corrosion in Heat Exchangers by John J. B. Rutherford, Babcock & Wilcox Tube Co., Beaver Falls, Pa.

March 5—Corrosion of Water Mains and Water Distribution Systems, speaker to be named.

April 2—Metallizing by Howard Van Pool, Metallizing Engineering Co., New York.

May 7—Corrosion of Radiant Heating Systems, speaker to be named.

All meetings are held at Mellon Institute.

San Diego Section's Petition Is Received

A petition for the organization of a section of the National Association of Corrosion Engineers at San Diego has been presented to Western Region Chairman W. M. Schilling for consideration by region officials and national officers.

NACE members in the San Diego region are expected to benefit from the new organization because many of them were unable to attend section meetings at Los Angeles regularly.

Chicago Committees Are Appointed

Committees to function in Chicago Section 1952-53 have been named as follows:

Program—R. W. Flournoy, chairman; Corn Products Refining Co., Argo, Ill.

Arrangements—F. J. Holsinger, chairman; Corn Products Refining Co., Argo, Ill.

Hospitality—R. L. Lothringer, chairman; Sinclair Research Lab., Harvey, Ill. R. G. Rydell, National Aluminate Corp., Chicago; A. H. Seymour, Corn Products Refining Co., Argo, Ill.; L. W. Peterson, Swift & Co., Chicago; S. Serbula, Jr., Allied Industrial Supply Co., Chicago.

Host—R. H. Weisert, chairman; Sales Engineering, Inc., Chicago; Len Rissiter, Industrial Coatings Corp., Chicago; F. P. Macdonald, Electro Rust-Proofing Corp., Chicago.

Membership—F. W. Pfohl, Amour & Co., Chicago; E. H. Kinelski, Pullman Standard Car Mfg. Co., Hammond, Ind., co-chairmen.

Publicity—R. B. Janota, Swift & Co., Research Lab., Chicago and W. L. Kinney, Standard Oil Co., Chicago, co-chairmen.

Vast Savings Possible From Good Surface Preparation Are Cited

A. J. Liebman of Dravo Corp. told 86 members and guests of New York Section November 5 up to $200,000,000 annually can be saved by using effective and economical methods of surface preparation. Mr. Liebman, assistant director of research for Dravo, discussed preparation of steel surfaces for painting. It is to the advantage of the user to properly specify the foundation on which paint is to be applied, Mr. Liebman said.

He went over costs, advantages and limitations of various surface preparation methods applicable to surfaces covered with stratified, heavy and light rust formations, mill scale and otherwise affected. A discussion followed.

Chairman Kempton H. Roll announced that L. P. Sudrabin would speak on cathodic protection principles at the December 3 meeting to be held at Schwartz Restaurant, 54 Broad St., New York City.

Letter Ballots for Officers Are Due Dec. 20

Letter ballots for officers of NACE to take office March 20, 1953, must be at Central Office not later than December 20. Officers nominated by the nominating committee and appearing on the ballot are: For President, Walter F. Rogers, Gulf Oil Co.; for vice-president, Aaron Wachter, Shell Development Co., and for treasurer, R. A. Brannon, Humble Pipe Line Co. For directors representing active members, three-year terms, W. F. Fair, Jr., Koppers Co., Inc., and R. L. Bullock, Interstate Oil Pipe Line Co. For director representing corporate members, three-year term, J. Pat Casey, Jr., Crane Co.

Provision is made on the ballot for the addition of write-in candidates.

Luce Will Talk at Philadelphia Dec. 12

Philadelphia Section's December 12 meeting at the Poor Richard Club is scheduled to hear Walter A. Luce of The Duriron Company, Dayton, Ohio. He will speak on "Recent Trends in Stainless Steel and Other High Alloys." Mr. Luce's long experience and technical training give authority to his remarks.

Dinner at 6:30 p.m. will precede the technical session, scheduled to begin at 7:30 p.m.

•

Paid circulation of CORROSION has increased every year since the magazine was founded.

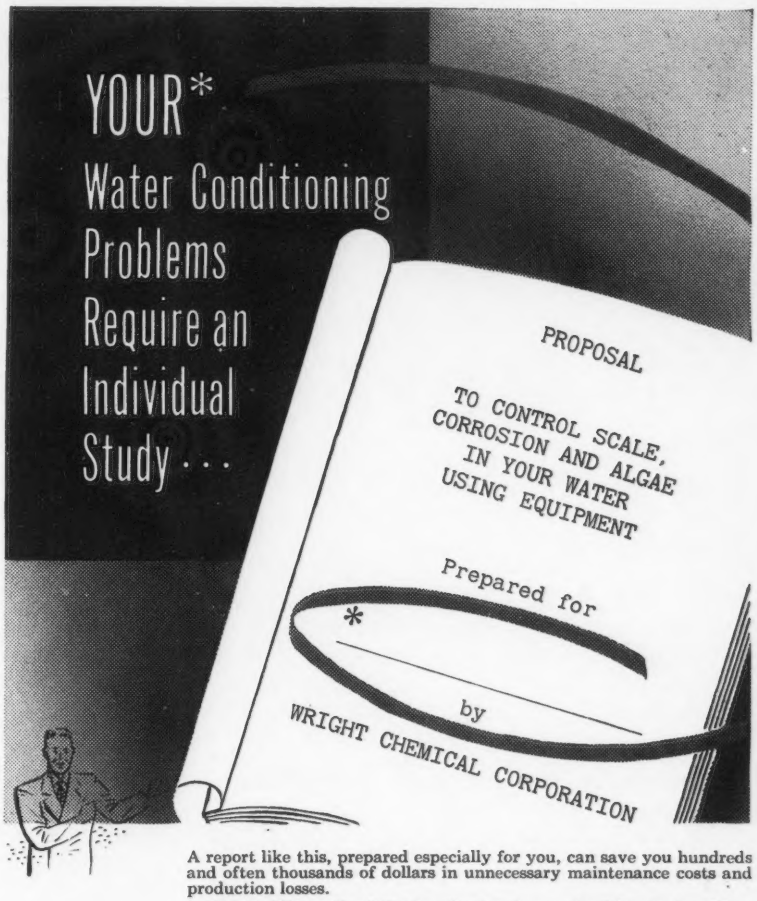
South Central Region To Meet Oct. 7-9, 1953

The 1953 meeting of South Central Region NACE will be held October 7-9 at Tulsa, with Mayo Hotel as headquarters. Decision concerning specific dates was withheld pending a canvass of 19 technical and trade organizations to resolve conflicting meeting arrangements.

Tulsa Section issued an invitation to the region for next year's meeting during the October conference at New Orleans.

•

The Inter-Society Corrosion Committee was organized to help eliminate duplicated research into corrosion matters.



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7 Papers Scheduled for Chemical Industry Symposium

More Chicago Technical Program Officials

Photographs and biographies of three more Chicago Technical Program officials are given below:

Fresh and Salt Water

V. V. Kendall, Corrosion Engineer, National Tube Division, United States Steel Company, chairman of the Fresh and Salt Water Symposium, was chairman of Pittsburgh Section in 1950, and was elected a director representing corporate membership in 1952. A member of Technical Practices Committee 1 since its organization, he was a contributor in its report on the investigation of corrosion in condensate wells. He currently is chairman of Technical Practices Committee 8 on Corrosion by Waters and of TP-10 on Corrosion Fatigue.

High Temperature

John J. B. Rutherford, chairman of the High Temperature Symposium, is a metallurgist at the Tubular Products Division of The Babcock & Wilcox Co., Beaver Falls, Pa. He is active in the development of tubular materials for use in steam, chemical, oil and food industries and comes into contact with all phases of corrosion in service. His experience in stainless steel technology extends over 20 years, making him one of the early investigators of intergranular corrosion of these steels. He is a member of Technical Practices Committee 1 on the Corrosion of Oil and Gas Well Equipment.

Chemical Industry

C. A. Cobery—A chemical engineer in the engineering department at Mallinckrodt Chemical Works, St. Louis, is a Group Leader of the Chemical Engineering Group in the department. The group is concerned with design of new installations and revision of existing plant equipment. This work is intimately connected with corrosion testing and the selection of materials on the basis of corrosion resistance. He holds a bachelor's degree in chemical engineering from West Virginia University, 1944; a master's degree in chemical engineering from Carnegie Institute of Technology, 1947, and a Ph.D. from University of Wisconsin, 1949. He is treasurer of St. Louis Section, NACE, and chairman of the Chemical Industry Symposium for the Chicago Conference.

Vinyl Materials Discussed

Harry M. Zimmerman of B. F. Goodrich Chemical Company was the scheduled speaker at the October 21 meeting of Chicago Section. His topic was "Vinyl Chloride and Rigid Polyvinyl Plastics."

North Texas Section Meeting Place Weighed

A permanent meeting place for North Texas Section is being considered by a committee. A location at Grand Prairie, about half way between Dallas and Fort Worth, cities in which the majority of the section's members live, is favored at present.

In addition to the program on cathodic protection given by E. P. Doremus of Cathodic Protection Service at the November 3 meeting at the Lennox Hotel, Grand Prairie, the following meetings and programs have been scheduled tentatively:

December 8—Metallurgy to be discussed by Herbert M. Cooley, Bethlehem Steel Co., Tulsa.

January 5—Water and Sewage Problems of the City of Dallas will be discussed by Henry J. Graeser, Dallas City Waterworks.

CONTRACTS FOR CHICAGO CONFERENCE EXHIBIT SPACE

A descriptive brochure and a copy of the contract and specifications containing an application for exhibit space for the Ninth Annual Exhibition of the National Association of Corrosion Engineers was mailed Oct. 20 to known prospects of record October 15. The exhibit will be held in connection with the annual conference at Hotel Sherman, Chicago, March 16-20, 1953.

- **Anyone interested in this exhibit who has not received the information listed above is invited to write promptly to NATIONAL ASSOCIATION OF CORROSION ENGINEERS, 1061 M & M Building, Houston 2, Texas, attention of A. B. Campbell, Executive Secretary, requesting copies.**

Three Papers for Oil, Gas Production Symposium Also Are Revealed

Seven papers are scheduled tentatively for delivery during the Chemical Industry Symposium during the 1953 NACE Conference at Chicago, March 16-20. They range in subject matter from the use of plastic materials to a discussion of statistical analyses of corrosion data. Three papers have been scheduled for the Oil and Gas Production Symposium.

The seven papers arranged for the Chemical Industry Symposium are:

Use of Plastic Materials in Anti-Corrosion Application, by J. L. Huscher, American Agile Corp.

Corrosion by Acids at High Temperatures by R. F. Miller, R. S. Treseder and A. Wachter, Shell Development Company.

Metallurgy of Corrosion by F. Prange, Phillips Petroleum Co.

Statistical Analysis of Corrosion Data by O. B. Ellis, Armco Steel Corp.

Corrosion Study in a Salt Plant by H. B. Rickert, Michigan Chemical Co. and H. O. Teeple, International Nickel Co.

The Behavior of Titanium in Sulfuric and Hydrochloric Acids by G. C. Kiefer, Allegheny Ludlum Steel Corp.

Papers scheduled for the Oil and Gas Production Symposium are:

Corrosion of Casing in Oil and Gas Wells by Jack L. Battle, Humble Oil & Refining Co.

Laboratory Methods for Evaluation of Inhibitors for Use in Oil and Gas Wells by C. E. Greco, United Gas Pipe Line Co., and J. C. Spalding, Jr., Sun Oil Co.

Controlling Corrosion in Sweet Oil Wells by H. E. Greenwell, Atlantic Refining Co.

Duesterberg Addresses Sabine-Neches Meeting

Some Aspects of the Application and Usage of Baked Type Coatings was the topic of G. J. Duesterberg, of Plastic Applicators of Houston before 46 members and guests of Sabine-Neches Section October 30. The dinner meeting was held at Sammy's Restaurant, Lake Charles, La.

R. P. Clarke was reelected section trustee for another year.

Next meeting of the section will be held December 3 at Orange, Texas.

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Abstracts published in the Corrosion Abstract Section of Corrosion are indexed according to the system compiled for use with the association's Corrosion Abstract Punch cards.

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The 1954 Conference and Exhibition of the National Association of Corrosion Engineers will be held March 15-19 at Kansas City, Mo.

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The NACE Committee on Education welcomes inquiries concerning the holding of cooperative short courses on corrosion. The association can frequently help with advice and otherwise educational institutions interested in holding such courses.

Corpus Christi Section's Meeting Date Changed

A change of meeting date from fourth Wednesday monthly to fourth Tuesday is being considered by Corpus Christi Section. Reports on the regional meeting at New Orleans, on the education committee's contact with A & M College of Texas and on work of technical practices committees was heard at the October 22 meeting of the section at the Princess Louise Hotel, Corpus Christi.

Three Short Courses Projected for 1953

At least three short courses on corrosion are already projected for 1953, a report by Norman Hackerman, chairman of the NACE Committee on Education indicates. These courses, to be given with NACE cooperation are tentatively scheduled as follows:

February—University of California at Berkeley.

September or October—A short course at Texas A. & M., College Station.

October—University of Illinois, Urbana. On cathodic protection.

In addition to these it has been the custom of the Tulsa Section and Shreveport Section each to hold short course sessions on pipe line corrosion in the fall. No information has been received that there will be a short course in West Texas sponsored by Permian Basin Section, but it is possible it will be held in 1953.

There is at least one other possible short course under discussion at a Southwest University for 1953.

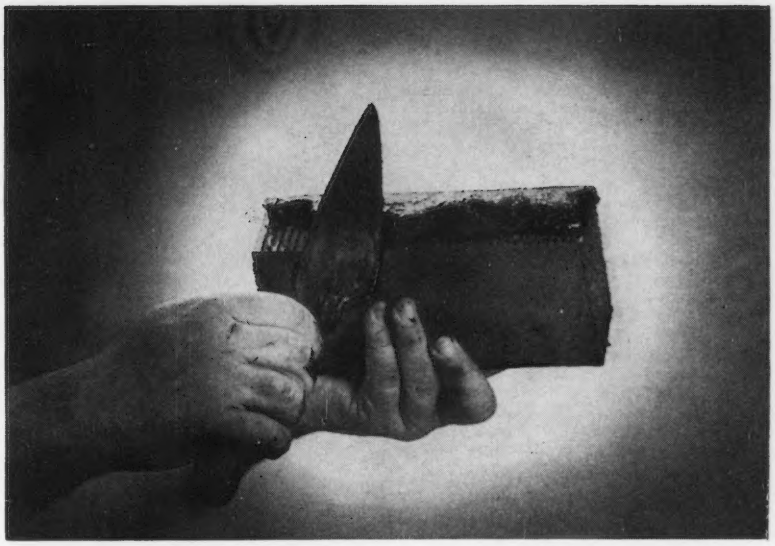
Dr. Hackerman also reported regularly scheduled courses in corrosion have appeared in several universities in the United States, those including Stevens Institute, University of Tennessee, University of Houston and the University of California. University of Delaware also has a new credit course on corrosion.

Three short courses sponsored by NACE were held at universities during 1952: University of Southern California at Los Angeles, in February with 250 registered; Case Institute of Technology at Cleveland in June and Washington University at St. Louis with 125 registered. Short courses on pipe line corrosion were held also by Tulsa Section in February and Shreveport Section in September.

The committee on education issued another request that regional and sectional officers supply names, addresses and topics which can be discussed by speakers known to be available for programs. The committee hopes to compile a list of speakers for the association's use.

Japanese Committee

An Electrolysis Control Committee of Japan has been formed to study means of controlling electrolysis and to handle literature connected with the study. This information was supplied by Hayata Shigeno, secretary of the Committee on Preventing Corrosion of the Government Chemical Industrial Research Institute, Tokyo.



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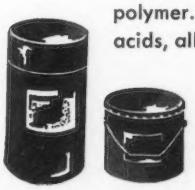

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Seventy Titles Appear In Annual Index

Seventy titles will appear in the Index to Corrosion Literature in this issue of CORROSION. Of the seventy articles published, eight are reprints of articles from other publications. The articles cover 440 pages.

In the alphabetical index to authors, 162 names are listed and credited to these authors, besides the seventy titles are 111 discussions.

More than 190 pages of Corrosion Abstracts were published in 1952 compared to only 114 pages in 1951, the gain being the result of the increased accrual of abstracts developed by the NACE Corrosion Abstract Card Service, and the increased amount of material available on corrosion. Substantial gains over 1951 were made also in total pages, with a tentative 1322 plus covers scheduled for this year compared to 1280 pages last year.

Ten "Topic of Month" Articles Are Published

A "Topic of the Month" article was published in each issue of CORROSION in 1952 except the July and October issues. Of the ten items published, four were reprinted.

Following is a list of the articles published this year:

Aluminum Alloys for Handling and Storage of Fuming Nitric Acid, by W. W. Binger, January.

Silicone Paint Protects High Temperature Refinery Equipment, by Max Leavenworth, February.

Ceramic Materials in Corrosive Service, by R. McFarland, March.

Galvanic Behavior of Tin Dipped Coatings on Copper Alloys, by F. L. LaQue, April.

Inner Coating a Corroded Gasoline Storage Tank With Concrete, by Edward H. Tandy, May.

Corrosion Problems in Ion Exchange Systems, by J. F. Wilkes, June.

Trifluorochloroethylene Polymer Resin Dispersion Films on Metal, by F. E. Gusmer, August.

All-Metal Containers Replace Wooden Ones for Aircraft Engines, September.

Graphitization of Cast-Iron Water Boxes on Surface Condensers Stopped by Insulation, by H. W. Wahlquist, November.

Early Iron Box Car's 63 Years' Service Include Civil War Combat Duty, December.

NACE Issues Three Numbered Publications

Numbered publications issued by NACE during 1952 were:

52-1—Guide for the Preparation and Presentation of Papers published, June, 1952.

52-2—Committee Directory, published August, 1952.

52-3—Sulfide Stress Corrosion Symposium, published October, 1952.

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Many, but not all, back issues of CORROSION are available for sale.

Annual Tabular Index Is in December Issue

A tabular cross-referenced index to the technical material published in Corrosion is included in this (December) issue of CORROSION. The table used is based on the NACE Abstract Filing Index and is substantially the same as that used for indexing the issues in Volumes 7 and 6 and for compiling the Five-Year Index to Corrosion Technical Material which was published in the December, 1950, issue. The only significant change is the addition of an eleventh subdivision to the second place of the table under the primary heading "5. Preventive Measures." This addition is "11. Design, Influence of." There also was a minor change in the designations of subdivision of "8. Industries" whereby Group 4 was altered to read "1. Fuel, Solids" and "2. Fuel, Gases." Added to this group also is "5. Atomic Energy."

The usual tabular index to Corrosion Abstracts, also based on the NACE Abstract Filing Systems, and in which cumulative page numbers of the abstract section are used, will be in the December issue. This index makes it possible for the researcher to determine in which issues and on which page numbers abstracts of interest to him are published, insofar as this is possible through classification to the second position of the abstract filing system.

British Corrosion Group Meetings Are Scheduled

Scheduled technical meetings of the Corrosion Group of the Society of Chemical Industry (British) for 1952-53 have been announced as follows:

Oct. 8—London. Discussion on Filiform Corrosion and Related Phenomena by R. J. Brown, F. Hargreaves, J. F. Kayser and C. F. Sharman.

Oct. 20—London. Papers on Tin-Nickel Alloy Coatings by R. M. Angles, S. C. Britton and D. G. Michael.

Nov. 20—London. Symposium on Caustic Cracking in Steam Boilers by A. A. Berk, P. Hamer, J. Lodder, R. N. Parkins, R. Rath, R. L. Rees and C. D. Weir.

Dec. 8—Sheffield. The corrosion Resistance of Stainless Steel by U. R. Evans.

Jan. 20—London. The Electrochemical Behavior of Metals and Corrosion by M. Pourbaix.

Feb. 5—Nottingham. Atmospheric Corrosion and Atmospheric Pollution by J. C. Hudson and J. F. Stanners.

Feb. 18—Newcastle-on-Tyne. Lectures on: Some Recent Advances in Corrosion Research by W. H. J. Vernon. Protective Coatings for Buried Pipelines by K. A. Spencer and H. B. Footner.

March 27—Manchester. Symposium on Corrosion Inhibitors by U. R. Evans, T. P. Hoar, W. S. Patterson, A. T. B. P. Squires, S. M. Todd and F. Wormwell.

April 15—London. The Corrosion of Aluminum and Its Alloy in Supply Waters by C. F. Porter.

May 13—London. Annual general meeting.

The Corrosion Group is organized among technical and engineering societies in Great Britain to assist in coordinating the activities of the several societies.

Two TP Reports Are Published During 1952

Two reports of NACE Technical Practices Committees were published in CORROSION during 1952. They were:

Sour Oil Well Corrosion—A Report by Technical Practices Committee 1D, by J. A. Caldwell, published in August, 1952.

Field Experience With Cracking of High Strength Steel in Sour Gas and Oil Wells, A Report of TP-1G, published in October, 1952.

BOOK REVIEWS

Annual Report 1951, National Bureau of Standards. National Bureau of Standards Miscellaneous Publications 204, 105 pages, 28 halftone illustrations, Government Printing Office, Washington 25, D. C., 50 cents. Summarizing scientific and engineering investigations conducted by NBS during the fiscal year 1951, this booklet contains accounts of current activities as well as more detailed descriptions of especially important scientific developments. Its text provides a general description of work done in the 15 scientific and technical divisions and gives many specific examples of significant projects at NBS during the year.

The scope of research and development at NBS is indicated by the names of these divisions: electricity, optics and metrology, heat and power, atomic and radiation physics, chemistry, mechanics, organic and fibrous materials, metallurgy, mineral products, building technology, applied mathematics, electronics, ordnance development (electromechanical fuzing, guided missile fuzing, projectile fuzing), radio propagation (ionospheric research, systems research, measurement standards), and missile development.

(Note: Foreign remittances must be in U. S. exchange and should include an additional one-third the publication price to cover mailing costs.)

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Symposium on Spectrographic Analysis of Diesel Engine Lubricating Oil. May 5-6, 1952, Schenectady, N. Y. Twelve authors' remarks at American Locomotive Co., sponsored meeting. 76 pages, 6 x 9 inches, paper bound. Availabiltiy not indicated.

An edited transcription of on-the-spot tape recordings of nine technical papers delivered at a symposium sponsored by American Locomotive Company attended by 86 representatives of 43 railroads. The papers show how spectrographic analysis has been adapted to Diesel engine maintenance by railroads. Detailed accounts of railroad experience with the spectrograph are given. It was reported the technique has been developed to the point considerable savings in maintenance and repair are being made by using railroads and breakdowns prevented.

Use of the spectrograph to determine the corrosion and wear qualities of all types of lubricating oils for engine and general machinery use is advocated.

Usefulness of the report is materially hampered by the lack of a topical index.

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Inquiries concerning advertising in CORROSION should be addressed to Central Office NACE, 1061 M & M Building, Houston 2, Texas.

Gas Technology Home Study Course Available

The Institute of Gas Technology, affiliated with the Illinois Institute of Technology, is offered the first of what is planned to be a comprehensive schedule of home study courses on gas. The first course, "Natural Gas Production and Transmission," consists of seventeen chapters or subdivisions. Instruction material is designed in convenient letterhead size. The courses are offered for all who wish to take them, regardless of previous experience, at $75 a year for persons who wish to take the course individually and have reports on studies graded and criticized. A second plan provides for time payments while a third plan at $37.50 provides for purchase of the instruction material only.

A review copy of Chapters V and VI among other things, says concerning casing selection, "Both internal and external corrosion, as well as internal abrasion by entrained sand particles or by action of the drill pipe, must be considered. This may require increased wall thickness or use of stronger alloy steels. Allowance must also be made for corrosion by well fluids and by acidizing solutions. Injection of corrosion inhibitors and cathodic protection are now receiving attention and may come into extensive use. At present a reasonable added wall thickness is allowed for this factor."

Corrosion Papers Given At AIEE Fall Meeting

Several papers on corrosion were presented during the American Institute of Electrical Engineers' fall general meeting at New Orleans October 13-17. Among the papers presented were:

Grounding and Corrosion Protection on Underground Electric Power Cable Sheaths and Oil or Gas Filled Pipe Lines by R. J. Kuhn, consulting engineer, New Orleans.

Measurement of Cathodic Protection Currents from Sacrificial Anodes by H. N. Hayward and R. M. Wainwright, University of Illinois.

The Use of Graphote Anodes for Cathodic Protection of the Bottoms of Inactivated Ships by J. P. Oliver, National Carbon Co

Cathodic Protection of Refinery Equipment, Derk Holsteyn, Shell Oil Co.

Cathodic Protection of Electrical Substations and Power Plants.

Battelle Changes Name Of Technical Magazine

The name of the Battelle Library Review has been changed to Battelle Technical Review, effective with January, 1952, the issue for which month was designated No. 1 of Volume 1. Because abstracts from Battelle are customarily carried in the various abstract publications of NACE, and because the name of the abstracting agencies is significant sometime, the code designation of Battelle Technical Review has been set as BTR. This designation will appear hereafter at the end of abstracts from Battelle Technical Review used by NACE. Abstracts from Battelle Library Review will retain the original designation, BLR.

Because increasing the degree of motion of a corroding solution brings more oxygen to the surface of the metal with which it is in contact, such increase has a decided influence on the rate of corrosion. In liquid that may appear quiet, convection currents are nonetheless at work slowly distributing dissolved oxygen throughout the solution. When velocity agitates the liquid-air interface, unsaturated liquid is brought to the surface layer and the oxygen-solution rate rapidly stepped up. At the same time the liquid film on the surface of the metal is thinned so that this increased amount of dissolved oxygen diffuses more readily. Thus the combined effect of more dissolved oxygen conveyed more rapidly to the metal is a marked acceleration of corrosion.

Velocity, too, is often the indirect if not the direct cause of mechanical erosion of metal, for the deterioration it helps bring about results in the formation of corrosion products. In a quiet system these might serve a protective function but with motion a factor they erode readily, leaving already weakened metal exposed to further corrosive attack.

The ever-varied interplay of its many governing factors render the mechanism of corrosion complex indeed. Recognizing effects, determining causes, and controlling those that can neither be eliminated nor regulated is a responsibility industry has long assigned to Dampney. The reduction of *your* corrosion problems through the medium of Dampney equipment-engineered protective coatings . . . formulations of vinyls, ceramics, asphaltums, silicones, chlorinated rubber and other natural and synthetic resins . . . is a responsibility we should likewise welcome.

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Abstract Card Service Seeks 1953 Subscriptions

More than 2100 cards will be issued under the 1952 subscription to the NACE Abstract Card Service. Conclusion of the 1952 subscription will mark the end of the second year of operation during which 4200 cards have been issued.

Subscriptions for the third calendar year, 1953, are being accepted now. The subscription price has been kept at $75 for the year pending further study of the cost of the service. First shipment of 1953 cards probably will be made late in January.

Research Foundation Is Established by ASTE

The first five trustees for the Tool Engineering Research Foundation was elected October 11 by the board of directors of the American Society of Tool Engineers. Elected at the ASTE 20th semi-annual meeting were Roger E. Gray, Bristol Brass Co., Bristol, Conn.; David A. Wallace, Chrysler Corp.; Robert B. Douglas, Godscroft Industries, Montreal; John Slezak, Turner Brass Co., Sycamore, Ill. and Louis F. Polk, Sheffield Corp., Dayton, Ohio. The meeting was held at Buffalo.

Grants to industrial laboratories, colleges and universities to carry out research projects in the manufacturing, manufacturing processes and allied tool engineering areas are contemplated. ASTE has appropriated $75,000 as an initial contribution to the establishment of the foundation.

Battelle Establishes New German Research Center

Battelle Memorial Institute has established a new research center at Frankfurt on Main in Germany to serve the industry of that country. Battelle also is establishing a research center at Geneva, Switzerland, and has set up a fellowship program for selected students in the universities of Switzerland and Germany. Research centers and fellowship programs for the other countries of Western Europe ane contemplated also.

The Frankfurt center will engage in chemical, metallurgical and engineering research.

ASTM Industrial Water Group Meets in January

Group 4-19 on Industrial Water of The American Society for Testing Materials will meet Jan. 26-28 in St. Louis, Mo. The Spring meeting and committee week of the ASTM will be held in Detroit, Mich., March 2-6, and the ASTM Annual Meeting will be held in Atlantic City, N. J., June 29-July 3.

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In each December issue of Corrosion there is published a tabular cross-indexed reference to all technical material published in the preceding 12 months. This table includes a chronological list of papers and authors, by page numbers and an alphabetical list of authors.

NACE

New Members and Changes of Address

• This list is published principally for use by NACE Regional and Sectional officers in keeping their mailing lists up to date.

(Additions through October 27, 1952)

CALIFORNIA

FULGHUM, CLARK, Owens-Corning Fiberglas Co., 68 Post St., San Francisco, Cal.
JORDA, ROBERT M., Shell Oil Company, Box 999, Bakersfield, Cal.
KERR, R. H., Southern California Gas Co., Box 3249 Terminal Annex, Los Angeles 54, Cal.
PARK, FRANK K., Escondido Mutual Water Co., 227 East Grand Ave., Escondido, Cal.

DELAWARE

SEITZ, GEORGE H., JR., Gates Engineering Co., P. O. Box 1711, Wilmington, Delaware.

FLORIDA

FAIR, CLEVELAND, M., W. W. Henderson & Sons, P. O. Box 1085, Pensacola, Florida.
HENDERSON, JOSEPH A., W. W. Henderson & Sons, P. O. Box 1085, Pensacola, Florida.
HENDERSON, WILLIAM W., W. W. Henderson & Sons, P. O. Box 1085, Pensacola, Florida.

GEORGIA

HALEY, HERBERT P., The Albany Coca-Cola Bottling Co., P. O. Box 1191, Albany, Georgia.

ILLINOIS

DUNCAN, DAVID L., U. S. Rubber Co., 4001 Wrightwood Ave., Chicago 39, Illinois.

LOUISIANA

BROCK, PHIL C., Dowell Incorporated, 160 Glynnwood Ave., Lafayette, La.
MARSHALL, JERRY R., The Texas Company, Box 146, Erath, La.
VIDOVIC, PAUL P., 4419 Mimosa, Baton Rouge, La.

MARYLAND

DIUGUID, JOHN H., Chesapeake & Potomac Telephone Co., 320 St. Paul Place, Baltimore 2, Md.

MASSACHUSETTS

ABBOTT, CHARLES T., Negea Service Corp., 10 Temple, Cambridge, Mass.

MICHIGAN

FINLAY, DANIEL F., The Hinchman Corp., 1207 Francis Palms Bldg., Detroit 1, Mich.

MISSOURI

KENYON, C. PATRICK, Sheffield Steel Corp., Sheffield Station, Kansas City 3, Mo.

NEW JERSEY

HOWARD, HARRY W., Shell Chemical Corp., 1120 Commerce Ave., Union, N. J.

NEW YORK

ANSON, E. H., Gibbs & Hill, Inc., 491 Pennsylvania Sta., New York 1, N. Y.
FOUTS, JOHN M., 605 Roycroft Blvd., Buffalo 25, N. Y.
FROGNER, WILLARD B., Hills-McCanna Co., 30 Church St., New York, N. Y.
HICKS, CHARLES P., Ebasco Services, Inc., 2 Rector St., New York 6, N. Y.
LORCH, ALBERT, Hudson View Gardens, Apt. G-31, New York 33, N. Y.
McBRIDE, JOHN S., Owens-Corning Fiberglas Corp., 16 E. 56th St., New York, N. Y.
McLAUGHLIN, HAROLD A., Central Hudson Gas & Elec. Corp., South Road, Poughkeepsie, N. Y.
MUSS, DAVID, Eng. Dept., Celanese Corp. of America, 2 Park Ave., New York 16, N. Y.

OHIO

DOUGLASS, DAVE M., Special Screw Products Co., 5445 Dunham Road, Bedford, Ohio.
VAGO, STEPHEN A., The Texas Co., 4201 River Road, Cincinnati, Ohio.

OKLAHOMA

POYHONEN, EINAR A., Oklahoma Natural Gas Co., 213 N. Broadway, Shawnee, Okla.
SAGE, JOHN F., Sinclair Research Laboratories, Inc., 860 North Lewis St., Tulsa, Okla.

PENNSYLVANIA

McCONNELL, CHARLES A., U. S. Army Air Force, MBMEE Olstead AFB, Middletown, Pa.

WISCONSIN

KOENIG, WILLIAM C., C. J. Koenig Co., 3223 South Indiana Ave., Milwaukee, Wisconsin.

TEXAS

EDMONSON, THOMAS C., 3807 Beechwood Lane, Dallas 9, Texas.
FLANDERS, F. D., Flanders Construction Co., Box 12188, Houston, Texas.
KOLL, ROBERT J., Diamond Alkali Co., P. O. Box 686, Pasadena, Texas.
MINER, LUCIEN L., JR., Allen D. Stafford, Inc., 1814 Richmond Ave., Houston, Texas.
NOWICKI, HARRY R., Ampco Metal Inc., 4215 Graustark St., Houston, Texas.
SCHROEDER, CHARLES D., Dearborn Chemical Co., 165 Green Acres, Amarillo, Texas.
STAFFORD, EDWIN O., Allen D. Stafford, Inc., 1814 Richmond, Houston, Texas.
VALLEY, ROBERT N., Inspector of Naval Material, U. S. Navy, P. O. Box 4090, Houston, Texas.

FOREIGN

CATES, CHARLES W., C. H. Cates & Sons, Ltd., P. O. Box 106, West Esplanade, North Vancouver, B. C., Canada.
CROFT, WILLIAM F., Koppers Products, Ltd., 159 Bay St., Rm. 217, Toronto 1, Ontario, Canada.
KUNATH, RICHARD P., Creole Petroleum Corp., Las Piedras, Estado Falcon, Venezuela, South America.
WALLACE, DAVID E., Burrard Dry Dock Co., Ltd., North Vancouver, B. C., Canada.
WYGARD, EDWARD J., Dr. Jose Polak, S. A., Edificio Polaquimia—P. O. Box 18981, Mexico 4, D. F., Mexico.

Changes of Address—

(Old Address Follows New in Parenthesis)

CALIFORNIA

BROWNE, JOHN J., General Petroleum Corp., Bin "D," Taft, Cal. (P. O. Box 726, Wilmington, Cal.)
EPSTEIN, SAUL, 5015 Varna Ave., Sherman Oaks, Cal. (Statham Laboratories, 12401 W. Olympic Blvd., Los Angeles 64, Cal.)
GRETHER, FRED, 7700 Ostrom Ave., Van Nuys, Cal. (Statham Lab., Inc., 12401 W. Olympic Blvd., Los Angeles 64, Cal.)
JONES, WILLIAM E., 1822 12th Ave., Los Angeles 19, Cal. (1726 Long St., Santa Clara, Cal.)
KERR, ROBERT H., Southern California Gas Co., Box 3249 Terminal Annex, Los Angeles, Cal. (810 S. Flower St.)

ILLINOIS

BOAZ, DONALD P., 4826 Forrest, Downers Grove, Ill. (2307 Nickolson Drive, Dallas, Texas.)
MATSON, EUGENE M., Universal Oil Products Co., 30 East Algonquin Road, Des Plaines, Ill. (310 South Michigan Ave., Chicago 4, Ill.)
PETRAS, GEORGE R., Universal Oil Co., 30 East Algonquin Road, Des Plaines, Ill. (310 South Michigan, Chicago 4, Ill.)
PREECE, ROBERT N., Rheem Manufacturing Co., 7600 South Kedzie Ave., Chicago, Ill. (4361 Firestone Blvd., Southgate, Cal.)
TUTTLE, LOREN W., Public Service Co., of Northern Illinois, 615 Eastern Ave., Bellwood, Ill. (Public Service Co. of Northern.)

IOWA

DANIELS, FRED A., JR., 2910 Brattleboro Ave., Des Moines 11, Iowa. (Electro Rust-Proofing Corp., N. J., 1085 27th St.)

LOUISIANA

MITCHELL, LEO S., 664 Lauricella Ave., New Orleans 21, La. (8228 Palm St.)
MUIRHEAD, D. A., Arkansas Fuel Oil, Box 1734, Shreveport, La. (Box 428, Olla, La.)

MASSACHUSETTS

BROWN, CHARLES G., New England Hard Facing Co., 678 Brookline Ave., Brookline 46, Mass. (United Carr Fastener Corp., 31 Ames, Cambridge, Mass.)
SMITH, EBEN O., 19 Chardon Road, West Medford 55, Mass. (Dist. Public Works Office, First Naval Dist., 495 Summer, Boston 10.)

MICHIGAN

GREBE, JOHN J., 1006 Helen St., Midland, Michigan. (Route 5.)

MISSOURI

BAUMSTARK, WALTER A., The Carpenter Steel Co., 8015 Forsyth Blvd., St. Louis 5, Missouri. (712 Cass Ave.)
ISAACKS, ALBERT N., 10801 E. 58th Terr., R. R. No. 5, Independence, Mo. (54 Revere Road, Apt. 3, Drexen Hill, Pa.)

NEW JERSEY

BALIN, WILLIAM, Maintenance Services Co., 391 Valley St.-rear, South Orange, N. J. (112 Academy St.)
KRYSTOW, PAUL, 100 Glenwood Ave., Jersey City, N. J. (Colgate Palmolive Peet Co., 105 Hudson St.)

NEW YORK

HAYES, WILLIAM B., Stauffer Chemical Co., Research Department, Chauncey, N. Y. (Box 616, Niagara Falls, N. Y.)
KEMP, JAMES T., 270 Jay St., Apt. 16-I, Brooklyn 1, New York. (American Brass

(Continued on Page 9)

Changes of Address—

(Continued From Page 8)

Co., 1511 K St., N.W., Washington 5, D. C.)
MATHERS, W. D., 29 Dumbarton Drive, Huntington, L. I., New York. (62 Buff Road, Tenafly, N. J.)
QUINLAN, JOSEPH F., Rt. 1, Charlton Road, Ballston Lake, New York. (Box 200, Rosendale Road, Schenectady, Rt. 1, N. Y.)

OHIO

CIBORSKI, JOHN M., National Lead Co. Res. Lab., P. O. Box 158, Mt. Healthy Station, Cincinnati 31, Ohio. (105 York St., Brooklyn 1, N. Y.)
HOCKER, C. RICHARD, 2775 Bremen Ave., Columbus 11, Ohio. (The Duriron Co., Dayton, Ohio.)
WEST, LEWIS H., Sohio Pipe Line Co., The Standard Oil Co., Products Pipe Line Dept., Box 631, Fostoria, Ohio. (Sohio Pipe Line Co.)
WILLGING, JAMES F., Ohio State Univ. Res. Found., Room 208, Eng. Exp. Station, Columbus, Ohio, (Willging.)

OKLAHOMA

SCHUELER, ROBERT C., 1664 Maple, Bartlesville, Okla. (2200 S. Dewey.)

VIRGINIA

DICKINSON, NANCYE RUTH, Dept. of Defence, Engineer Research & Dev. Labs., Bldg., 318, Fort Belvoir, Virginia, (Belvoir.)

TEXAS

CARPENTER, G. CAREY, 9918 Lenel Drive, Dallas 9, Texas. (4026 Parkside Drive.)
CUSHMAN, GEORGE A., Municipal Light & Power System, P. O. 118, Gonzales, Texas. (Box 361, Brenham.)
GARNER, CORDELLE L., 5214 Southlea St., Houston 21, Texas. (3315 Sackett.)
CROSS, LEWIS, Taylor Oil & Gas Co., Box 4067, Corpus Christi, Texas. (Taylor Refining Co., Frontier Oil & Gas Bldg., McAllen, Texas.)
JOYCE, EDWIN, American Petroleum Institute, 300 Corrigan Tower Bldg., Dallas 1, Texas. (816 Rio Grande National Bldg.)
LUGER, KARL E., K. E. Luger Company, P. O. Box 6704, Houston 5, Texas. (2716 Danville St.)
MOORE, EARL D., 1304 Alma, Victoria, Texas. (10229 Chadwick, Houston, Texas.)
WHITLEY, B. J., JR., Tennessee Gas Transmission Co., P. O. Box 268, Victoria, Texas. (P. O. Box 98, Hamburg, N. Y.)

FOREIGN

McCAMMON, G. A., Chief Engineer, Attn. Tech. Library, D73233-CCD-650, Creole Petroleum Corp., Apartado 889, Caracas, Venezuela, S. A. (D49473-CCD-342.)

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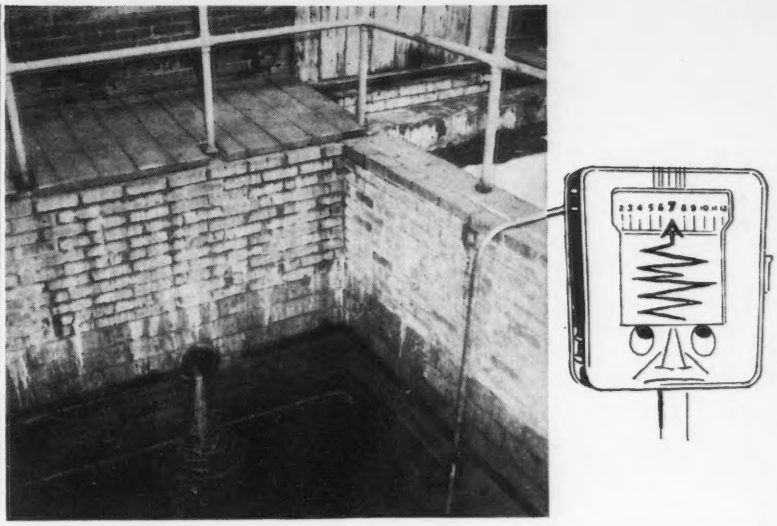

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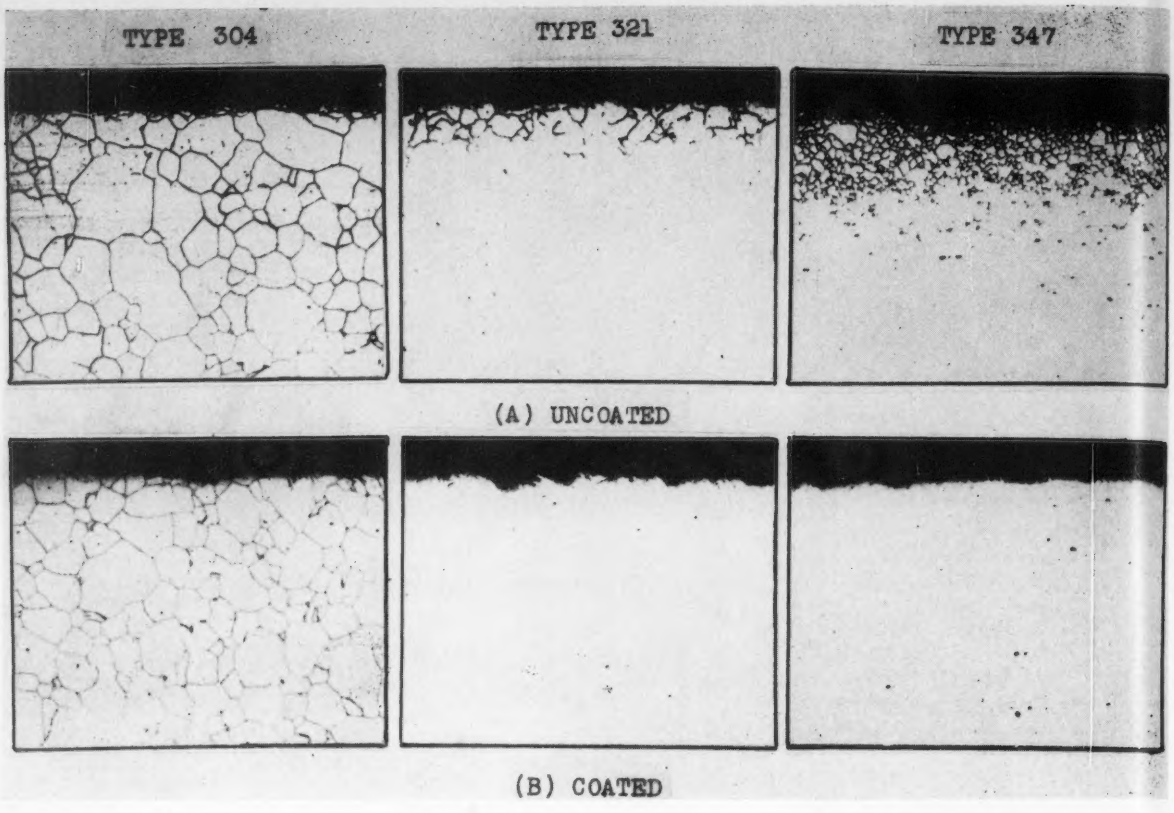

Figure 1—Photomicrographs of etched stainless-steel specimens after carburizing for four hours at 1650 degrees F. Upper specimens uncoated; lower specimens coated with National Bureau of Standards ceramic coating A-19H. The coated specimens of Types 321 and 347 show none of the carbon absorption that is evident in the uncoated specimens. The heat treatment alone causes carbide precipitation in Type 304; however, the carbide network is heavier near the surface of the uncoated specimen. (Approx. X100.)

Ceramic Coatings Prevent Precipitation Of Carbides in Heated Stainless Steels

SOME of the stainless steels used in aircraft exhaust systems tend to absorb carbon under severe operating conditions. This causes precipitation of carbides at or near grain boundaries, which may result in failures of exhaust parts.

The National Bureau of Standards has demonstrated in recent laboratory tests that certain NBS ceramic coatings successfully prevent this undesirable carbon absorption. Investigated were several NBS ceramic coatings, including types A-417 and A-19H, applied to three 18-8 stainless steels: AISI types 304, 321 and 347. Coated and uncoated specimens of the alloys were subjected to strongly carburizing conditions at 1350, 1500 and 1650 degrees F. The study was conducted by J. W. Pitts and D. G. Moore of the NBS enameled metals laboratory under sponsorship of the National Advisory Committee for Aeronautics.*

NBS has been active for a number of years in developing ceramic protective coatings for metals, particularly for alloys subjected to the high temperatures of aircraft exhaust systems. This work has resulted in several successful NBS coating formulations that are now in regular commercial use. Earlier NBS studies have demonstrated the ability of ceramic coatings to protect alloys from oxygen and lead bromide, but until now there have been no reported studies of the effectiveness of the coatings in preventing carbon penetration.

In the present study, small sheets of the various coated and uncoated alloys were packed in an alloy box with a commercial carburizing compound. The box was then placed in a furnace and slowly heated to one of the three selected temperatures. After four hours at this temperature, the box was removed from the furnace and allowed to cool in air.

Specimens thus treated were examined for significant changes in surface appearance and were then sectioned, etched and examined metallographically. Although some of the coated specimens showed blistering, spalling or wrinkling, in no case did the metal become exposed. Most of the uncoated specimens gave evidence of carbon absorption to depths as great as 0.007 inch below the surface. In most cases, however, the ceramic coatings completely prevented the absorption.

Of those studied, NBS ceramic coating A-19H proved most effective in preventing carbon absorption under all test conditions. However, the extreme severity of the test carburizing conditions would probably never be encountered in the practical operation of aircraft exhaust systems and any of several coatings might well prove fully satisfactory in service. Service testing of coated exhaust parts is probably the only really valid method now available for establishing the relative merits of different ceramic coatings.

* This study is reported in greater detail in NACA Technical Note 2572, "Ceramic Coatings for Prevention of Carbon Absorption in Four Heat-Resistant Alloys," by Joseph W. Pitts and Dwight G. Moore (December 1951).

New ASTM Standards Now Being Published

The American Society for Testing Materials has established several new standards for testing materials. All of the new and revised specifications will appear in the 1952 Book of ASTM Standards which is being printed now. In addition to being published in the large book, some specifications and standards will be published separately. Included in an advance publication under the heading of Corrosion of Iron and Steel are a "Tentative Specifications for Zinc-Coated Steel Overhead Ground Wire Strand." This specification was developed because of the need for such a product as specified by the Bureau of Reclamation and several utilities.

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Persons interested in joining NACE may get information and application blanks for membership by writing to Central Office, 1061 M & M Building, Houston 2, Texas.

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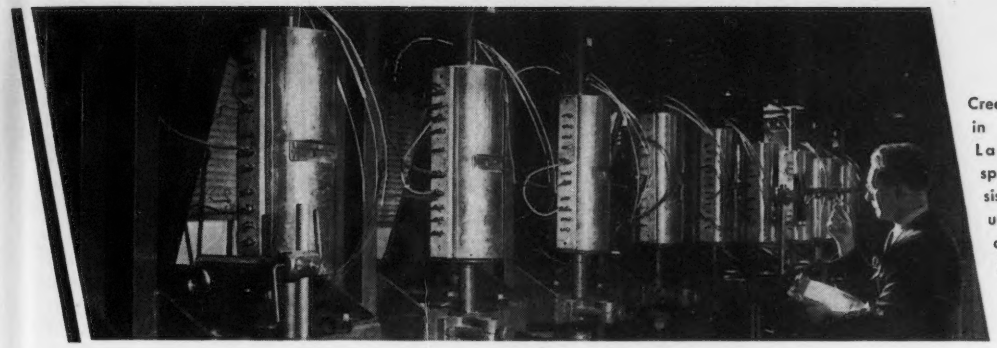
The 12-issue subscription price of CORROSION to non-members of NACE is now $9. The single copy price to non-members is $1.



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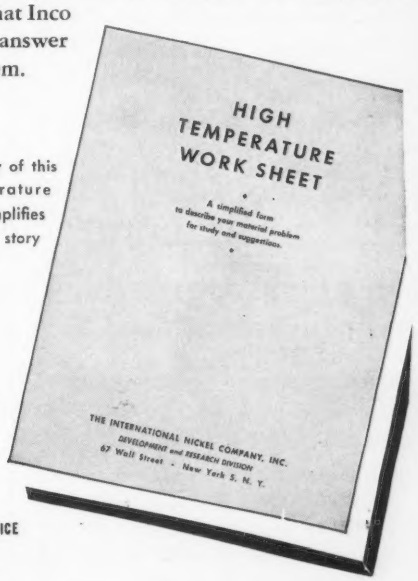
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PERSONALS

Carl E. Johnson has been named chief engineer at Scaife Company, Oakmont, Pa.

•

Lewis C. Rowland, superintendent of fabrication for Synthane Corp., Oaks, Pa. retired recently after 22 years' service.

•

Fred H. Haggerson, chairman of the board of Union Carbide and Carbon Corp., died at Roosevelt Hospital, New York City at 68 years of age October 14. He had been with Union Carbide over 33 years and became chairman of the board in 1951.

•

Robert E. Dunham has been named resident sales engineer for Graver Tank & Mfg. Co., Inc. at its Pittsburgh district office, 401-B Grant Bldg.

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NEW PRODUCTS —Materials—Service—Literature

Engineering Electroforming, a 6-page reprint from the Monthly Review, publication of the American Electroplaters' Society, describes how three commonly electroformed metals, copper, iron and nickel are compared. Copies are available from the International Nickel Co., Inc., Dept. EZ, New York 5, N. Y.

•

Erico Products Inc., 2070 East 61st Place, Cleveland 3, Ohio has just published a loose-leaf 72-page electrical connection catalog. The various types and sizes of connections and illustrations showing the use of Cadweld welders and accessories is included. Tables give cable and cartridge sizes, procedures are outlined and various accessories are enumerated.

•

The American Welding Society has published "Recommended Practices for Metallizing: Part IB—Application of Zinc and Aluminum for Protection of Iron and Steel." The booklet covers in detail the materials and equipment to be used; techniques of blasting and spraying and inspection procedures for verifying the adequacy of the coating. Also covered is the use of organic coatings as an additional protective measure. The last section gives typical coatings for various exposures including general atmospheres, salt atmospheres, industrial atmospheres and fresh and sea water. Copies are available at 50 cents each from the American Welding Society, 33 West 39th St., New York 18, N. Y.

•

The National Lead Burning Association has instituted a new program for the preparation and distribution of engineering and technical data on the uses of lead. According to association spokesmen, the program is in response to the growing need for lead construction in the chemical and process industries.

•

"Industrial Research Newsletter" published by Armour Research Foundation of Illinois Institute of Technology states that the first very-high-frequency transistors have been developed by Radio Corporation of America, RCA Building, 30 Rockefeller Plaza, New York 30, N. Y. Frequencies as high as 225 megacycles are reported giving promise of applications in television, FM radio, point-to-point radio communication.

•

An International Nickel Co., Inc., display "Reduction of Wear in Automobile Engines," was featured by the Chicago Section of the American Chemical Society in its Chemical Trail Blazers Exhibition at the National Chemical Exposition, Chicago in Sept. The display was based on work done by F. L. LaQue and E. J. Hergenroether, Development and Research Div., The International Nickel Co. The results of the investigation show that most of the wear of automobile engines is caused by corrosion. When operated at temperatures below the dew point of the products of combustion, such agents as carbonic acid, sulfuric acid, organic acids and halogen acids cause the damage, the investigation showed.

Stoner-Mudge, Inc., 2000 Westhall St., Pittsburgh 33, Pa., have published a brochure describing "Stonite," a phenolic coating. The coating is said to have excellent chemical and alkali resistance.

•

The Pressed Steel Co., Wilkes-Barre, Penna. has published illustrated catalog No 52 showing the company's line of heat-treating equipment. Containers, fixtures and retorts more commonly used in carburizing, annealing and installation views of new equipment are shown. The catalog also describes the various types of tubing for annealing, firing radiant furnaces, venting noxious gases and protecting thermocouples, which the company fabricates from heat and corrosion-resistant sheet alloys.

•

The Cooper Alloy Foundry Co., Hillside, N. J., has published a four-page brochure on the production of "Quikup," the firm's pipe coupling which they say will cut installation cost and effect material savings.

•

North American Phillips Co., Inc., 750 S. Fulton Ave., Mt. Vernon, N. Y. has published a small booklet, "Facts and Figures on 3 Powerful X-Ray Tools." The three machines are x-ray film diffraction, geiger-counter x-ray spectrometer, x-ray spectrograph.

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Heil Process Equipment Corp., 12901 Elmwood Ave., Cleveland, Ohio are makers of a complete line of solid plastic corrosion-proof fume ducts, hoods and accessory equipment. General construction is offered in polyester glass combinations as well as Rigivin, rigid vinyl type and Rigidene, polyethylene type.

•

The Permutit Co., 330 West 42nd St., New York 36, N. Y. has published a 16-page bulletin on the economies effected by eliminating the troubles caused by hard water. The bulletin explains the three basic types of ion-exchange equipment and shows how these units can be utilized.

•

Isotope Products Limited has used iridium 192 and photographic film to inspect 2000 feet of welded seam on a 48-foot diameter Hortonsphere at Polymer Corp., plant, Sarnia, Canada. Approximately 100 curies of iridium 192 was used. This isotope source was suspended on a chain which dropped it from the shielded lead box and lowered it into the tank. The iridium source was left in position 16 hours. Radiographs of every weld and of nozzles and manholes were produced.

•

The Kelite Power-Master steam cleaning machine is described in a free brochure published by the firm. Designed for heavy duty, the Power-Master has a rated steam capacity of 300 gallons per hour plus the exclusive Power-Blast rinsing-washing feature which delivers 1000 gallons of hot or cold water per hour at 500 psi. Address of the firm is: Kelite Products, Inc., 1250 N. Main St., Los Angeles 12, Calif.

Linatex, a special form of natural rubber manufactured in Malaya is described in a brochure issued by the Linatex Corporation of America, Rockville, Conn. The brochure states Linatex is completely resistant to moisture, is from three to four times more resilent than other rubbers and is light in weight, having a specific gravity of 0.97. Resistance to low temperatures is good and Linatex will withstand abrasion, corrosion and vibration. It will withstand the corrosive action of many chemicals.

•

The Buffalo Electro-Chemical Co., Inc., Station B, Buffalo 7, N. Y. have published Bulletin No. 39, "Surface Treatment of Metals With Peroxygen Compounds." Various types of surface preparation using peroxygen compounds are given in some detail, and more than 15 different sources are listed in the reference. The bulletin describes use of hydrogen peroxide, compounds forming hydrogen peroxide in solution, persulfates and peracids. The bulletin which describes the chemical and physical properties of these and other peroxygen compounds is available from the manufacturer.

•

The Bakelite Company, A Division of Union Carbide and Carbon Corp., 30 East 42nd St., New York 17, N. Y., has published technical release No. 6 on "Vinylite" Resin VAGH for Coatings, Properties and Uses. Composition, general characteristics, solubility, compatability, softening point, plasticization, moisture resistance, heat and light stability, pigmentation, adhesion, insolubilization are all given. Suggested uses are: as the major vehicle, over wash primers, marine systems, industrial metal protection systems, coatings for wood, paper coatings, fortification of other vehicles, metal decorating and container coatings, metal finishes and adhesives.

•

Bakelite Company has completed a new phenol plant at Marietta, Ohio.

•

The Babcock & Wilcox Co., Bever Falls, Pa. describes in a new technical data card, two economical stainless tubing steels having the attributes of resistance to corrosion and oxidation and also the ability to be hardened by heat treatment to develop good mechanical properties. The metals are designated B&W Croloy 12 and B&W 12-2. Those interested can obtain the card by writing for Technical Data Card 143, and addressing the company's office.

•

The International Nickel Company, Inc., 67 Wall St., New York 5, N. Y. is publisher of a booklet, "The Effect of Copper Undercoats on the Protective Value of Nickel.Chromium Coatings on Steel." The book gives the results of an 18-month study on high carbon steel panels plated with nickel-chromium and with copper-nickel chromium coatings and subjected to atmospheric and accelerated exposure tests. It was concluded that generally, composite coatings of copper and nickel were inferior to solid nickel coatings of equal thickness.

(Continued on Page 16)

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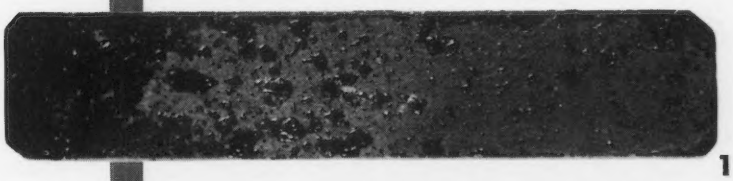
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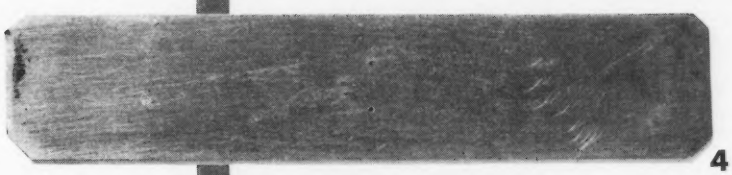
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Monsanto Santolene C, added to light petroleum products, controls corrosion. Take a look at the metal strips illustrated here and you'll see the results of Santolene C applied at various concentrations.

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SANTOLENE C

MONSANTO
CHEMICALS AND PLASTICS

SERVING INDUSTRY... WHICH SERVES MANKIND

New Products—

(Continued From Page 14)

United Chromium, Inc., 100 East 42nd Street, New York 17, N. Y. states that its product, Unichrome Coating 218X and other Unichrome plastisol compounds are being used increasingly where chemical resistance, resiliency and physical durability are required. Some of the uses are: Lining for ventilating ducts in handling strong acid fumes, lining for tanks to hold acids, alkalies, plating and cleaning solutions and other corrosives and as a protective coating for piping that is submerged or subject to spray.

•

The Tubular Products Division of The Babcock & Wilcox Co. has published an illustrated article on corrosion as a major factor in shortening the life of boiler tubes. The article points out the various types and causes of corrosion and offers a number of general rules to follow to get maximum service life for boiler tubing. Free reprints may be obtained by writing to the general sales offices of the division's welded tube works at Alliance, Ohio.

•

Magnesium anodes clamped to the hull of the tanker Marine Chemist, operated by the Dow Chemical Company, have substantially reduced corrosion of the hull it was learned when the vessel was drydocked at Brooklyn. The test of a years' duration revealed that the anodes had descaled much of the rust previously on the hull, leaving the surface smooth.

•

Polystyrene molded containers are used for the new 2 and 3-cell Exide-Manchex batteries made by Electric Storage Battery Company, Box 8109, Philadelphia 1, Pa. The permanent seal between containers and covers eliminates leakage of the electrolyte. Microporous rubber insulators and slotted plastic sheets are used as insulators between plates.

•

Craig & Pullen, 338 Ward Ave., Honolulu, Hawaii has been appointed a representative of Insul-Mastic Corp. in the Territory of Hawaii.

•

Vinylite, Bakelite Polyethylene and phenolic plastics and resins used for packaging operations are described in a 12-page reference pamphlet available from Bakelite Co., 300 Madison Ave., New York 17, N. Y.

•

MC 409, a new modified polystyrene with improved shock resistance as well as excellent heat resistance has been developed by the Chemical Division of Koppers Co., Inc., Pittsburgh. The new material has shown ASTM heat distortion temperature values as high as 198 degrees F. It is available in all opaque colors and has a high surface gloss.

•

Research and Control Instruments Div., North American Phillips Co., Inc., 750 South Fulton Ave., Mount Vernon, N.Y. has developed a new approach to the identification and quantitative analysis of minute amounts of elements present in very thin films or small deposits. The new method makes possible easy identification of coatings of 6 micrograms per square centimeter or less of stainless steel on plastic and metal bases. It quickly and easily determines the percentages of chromium and nickel present in a specimen of 18-8 stainless steel where one square centimeter of the film actually contains about one microgram of chromium and less than one-half microgram of nickel. The instrument used is an X-ray spectograph employing tungsten radiation but using a special analyzing crystal with newly developed optics. It is a non-destructive method.

•

American Flexible Metal Hose and Tubing, a 16-page illustrated catalog describes seamless and strip-wound types manufactured by The American Brass Co., American Metal Hose Branch, Waterbury 20, Conn. The tubing is made in bronze, steel, Monel, super nickel, stainless steel, brass and other workable metals. Copies of the catalog, CC-400 are available on request.

•

High Speed Nickel Plating, reprinted from the March, 1945 issue of the American Electroplaters' Review, eight pages, illustrated, gives results of investigations of plating deposits of .001 to .003-inch in eleven minutes at current densities of 100 to 300 amperes per square foot. Deposits exhibited equal corrosion resistance and compared in smoothness, buffing and mechanical characteristics with deposits from Watts type bath. Plating and solution procedures are given. Copies may be obtained from the International Nickel Co., Inc., Dept. EZ, New York 5, N. Y.

•

Research activities of Chase Brass & Copper Co., Inc., Waterbury, Conn. have been expanded under the direction of Dr. D. K. Crampton.

•

Engineering Corporation of America is the new name of Jefferies Engineering Co. of Westfield, N. J.

•

W. S. Shamban & Co., 5747 Marilyn Ave., Culver City, Cal. is producing three new series of O-rings designed for sealing applications where other elastomers are unsatisfactory. They have been designated Kelon-T (Teflon), Kelon-F (Kel-F Fluorothene), Nylon and Polyethylene. They have the properties of their respective materials.

•

Vacseal solids and acid handling pumps in 2, 3, 4, 6 and 8-inch sizes are manufactured by The Galigher Company, 545 West Eighth South, Salt Lake City, Utah. Because of a special construction feature the pumps are said by the manufacturer to be virtually glandless. This feature consists of an impeller disc with pumping vanes on one side and smaller auxiliary vanes on a greater diameter on the reverse side next to the gland. These auxiliary vanes create a vacuum on the shaft seal and prevent solids from cutting the shaft or packing. Rubber lined pumps have lining vulcanized to cast iron parts with thermosetting cement. This type can be adapted for acid service by changing the gland bushing and installing a shaft sleeve.

•

Berlin & Jones Company, Inc., 601 West 26th St., New York 1, N. Y., has issued an advertising mailing piece on its dry vapor "Pack-velopes," impregnated with a vapor corrosion inhibitor. The inhibitor used is dicyclohexylammonium nitrite. While it will not protect all metals, the protection it affords steel and aluminum is excellent, the firm says. Almost anything from 20-ton Diesel engines to small watch parts can be protected by the impregnated paper wrapping. The inhibitor is said to work particularly well in moist atmospheres. The paper wrapping eliminates the need for cosmoline, oil and grease as corrosion inhibitors.

•

Plax Corp., West Hartford, Conn. is molding 6½ and 13-gallon polyethylene bottles as shipping containers for hydrofluoric acid. Use of the plastic carboys has been approved by the Interstate Commerce Commission for hydrofluoric acid of not over 60 percent strength. The bottles, said to be the largest made of polyethylene, are blow molded, then assembled with an outer plywood jacket into the complete ICC-1F carboy unit.

•

The American Agile Corp., Box 168, Bedford, Ohio are manufacturers of corrosion-resistant tank liners made of "Agilene" (polyethylene) and "Agilide" (unplasticized polyvinyl chloride). Chemical inertness of these materials and the welding method employed in the fabrications of tank liners minimizes tank leaks, maintenance cost and provides high resistance to corrosion, the firm says.

•

The H. M. Harper Co., Morton Grove, Ill., manufacturers of non-ferrous bolts and nuts announces it has begun construction on another addition to its plant. The firm specializes in making high temperature fastenings used in the jet engine industry.

•

Anaconda Copper Mining Co. announces completion of the organization of its subsidiary, Anaconda Aluminum Co. (formerly Harvey Machine Co., Inc. of Montana). Francis O. Case, a vice-president of Anaconda Copper Mining Co., has been elected president of Anaconda Aluminum Co. The aluminum reduction plant will be built near Columbia Falls, at the base of Teakettle Mountain. The plant will cost $45,000,000 and will produce 50,000 tons of aluminum annually.

PERSONALS

The American Chemical Paint Co., Ambler, Penna., plans to open its new plant at Niles, Calif. the first of November. The plant will produce metal-working chemicals (rust proofing and paint-bounding phosphate coating chemicals, pickling acid inhibitors) and agricultural chemicals (plant hormones and "Weed-one" weed killers). **Mr. George H. Williamson,** former executive in the firm's Detroit, Mich. office has been selected to operate the new plant.

•

Eugene V. Ivanso, a member of NACE, has been named head of metallurgical engineering and research at Detroit Testing Laboratory, **Douglas Dow,** president announced. Mr. Ivanso has been a metallurgical engineer in Detroit for 16 years, affiliated with Bundy Tubing Co., Wyandotte Chemicals Corp. and Steel Sales Corp.

•

R. M. Hollingshead Corp. announces appointment of **A. E. Moore, V. M. Mantz** and **Dr. V. Esposito** to positions in the firm's Research and Development Division. Mr. Moore has been appointed vice-president and director of research and development. Mr. Mantz has been appointed director of Government and

(Continued on Page 18)

NEW

Facts and Technical Data on Alcoa's New, All-Purpose, Corrosion-Resistant Coiled Tube

Send for this new booklet describing Alcoa's new aluminum coiled tube—UTILITUBE.* Alcoa UTILITUBE is designed for instrumentation, fuel, air and lubrication applications. It is easier to form, flare and bend than annealed copper. It will save you up to 40% on tube costs—gives you 3 times more feet per pound. It comes in standard 50- and 100-foot lengths and in economical, long lengths up to 1,000 feet in some sizes.

UTILITUBE and fittings are available from your aluminum distributor. Look for his name in your classified telephone directory. Write:

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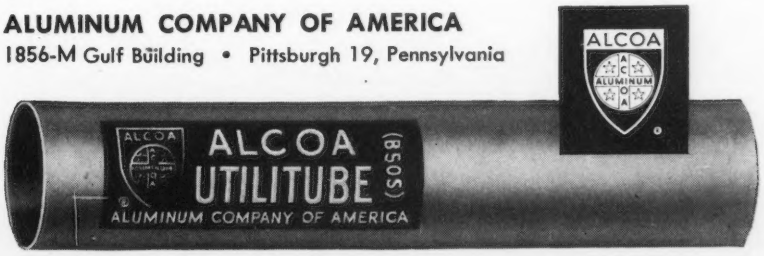

PERSONALS

(Continued From Page 16)

Industrial Research under Mr. Moore. Dr. Esposito will be director of new products development, succeeding Mr. Moore.

•

Arthur C. Bryan has been appointed vice-president in charge of sales for National Carbon Company, a division of Union Carbide and Carbon Corp. He started with the company in 1935 as an industrial salesman in the Chicago office. He is a native of Nebraska.

•

E. R. Shepard, formerly in charge of geophysical exploration for the Army Corps of Engineers is now head of the Geophysical Exploration Division of the Georator Company, Arlington, Va.

•

Chester M. Adams has been named general sales manager of The Bridgeport Brass Co., Bridgeport, Conn. **George H. Baldwin** has been named assistant to Mr. Adams and **Richard L. Allen** is now sales manager of mill products.

•

Cliffort R. Palkie has joined the staff of United Chromium, Incorporated as assistant sales manager of its Organic Coatings Div. He will supervise sales of vinyl chlorinated rubber and phenolic coatings. Before coming with United Chromium, Mr. Palkie spent six years with the Corrosite Corp., the last two years of which were spent as assistant sales manager.

•

F. H. Ebbert is now vice-president and general sales manager for the Gustin-Bacon Manufacturing Co., Kansas City, Mo. Mr. Ebbert has been vice-president and sales manager of the company's automotive division since 1946. In his new capacity, he will have charge of the company's four sales divisions, which are glass fiber insulation products, industrial, railroad, and automotive.

•

J. W. Ross has been appointed Philadelphia district manager for Carbide and Carbon Chemicals Co., a Division of Union Carbide and Carbon Corp. Mr. Ross joined the company in 1936. He came to Philadelphia from Atlanta in 1944. He moves up to fill the position formerly held by **R. M. Joslin, Jr.,** who has been appointed Midwestern division manager for the company in Chicago.

•

Frank J. Kiernan has been appointed sales engineer for the U. S. Stoneware Co., Akron, Ohio. Mr. Kiernan holds a B.S. degree in chemical engineering from the University of Detroit. He has wide experience in the field of organic and fine chemicals for a number of years.

•

William L. Keady, former president of the United States Gypsum Co. and the Marathon Paper Co. has been elected president of Pabco Products, Inc. and named a member of its board of directors. William H. Lowe, president of Pabco Products, Inc. was elevated to the chairmanship of the board replacing **Richard S. Shainwald** who was made honorary chairman of the board.

•

Hugh J. Fraser, vice president in general charge of all plant operations in the United States of The International Nickel Co., Inc., died in a Montreal, Canada hospital in August. He was 55 years old. Mr. Fraser was born in Brockville, Ontario, Canada and graduated from Queen's University at Kingston, Ontario, Canada with a bachelor of science degree. He joined the Huntington, West Virginia works of the International Nickel Co., Inc., in 1923, was promoted to assistant manager of the production department in 1935, was elected vice president in 1947 and a few months later was made vice president in general charge of all plant operations in the United States. Mr. Fraser was a member of the Canadian Institute of Mining and Metallurgy, American Institute of Mining and Metallurgical Engineers, American Society for Metals, the Mining and Metallurgical Society of America and the Canadian Society of New York. He was also a member of several social clubs.

•

James A. Rabbitt, Inco consulting engineer, who has spent much of his time in Japan and the Far East has retired from active service with the International Nickel Co. One of his first undertakings after joining International Nickel in 1929 was a survey of the industries of Japan. From 1932 to 1940, he was adviser and acting director of the company's Japan Nickel Information Bureau and also editor-in-chief of the Japan Nickel Review, a quarterly metallurgical journal. During World War II, Mr. Rabbitt served as Far Eastern adviser to the government. After the war he returned to Japan as Inco consulting engineer.

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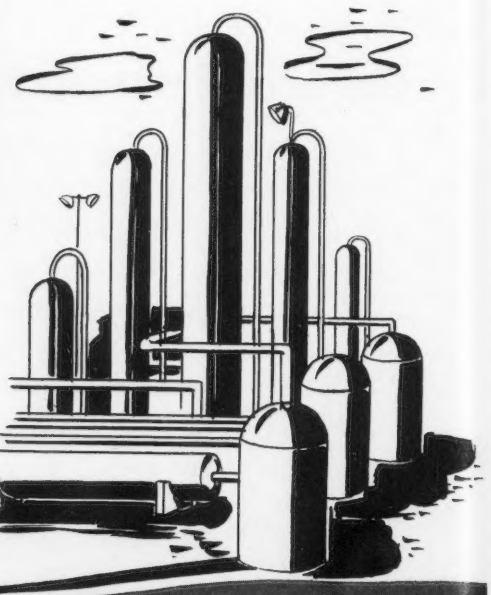
Acclaim our new, Effective
"COPON"



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Corrosion Abstracts

NATIONAL ASSOCIATION OF CORROSION ENGINEERS

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Vol. 8 December, 1952 No. 12

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NATIONAL ASSOCIATION of CORROSION ENGINEERS

1061 M & M Bldg. Houston, Texas

1. GENERAL

1.2 Importance

1.2.4, 6.1

Engineering Materials in Ordnance Equipment. B. S. MESICK. *Materials & Methods*, 33, No. 5, 59-63 (1951) May.

Military applications of steel and iron, non-ferrous metals [copper, aluminum, magnesium, titanium], rubber, plastics, adhesives and organic coatings.—BNF.

1.2.4, 6.6.8

The Promise of Reinforced Plastics in Defense—Part 3. *Modern Plastics*, 28, No. 9, 64-67 (1951) May.

In the previous two articles in this series, the types of resins and fibrous glass reinforcement now available were outlined, general conclusions were drawn regarding the military potentialities of these materials, the important part that armed forces development agencies have played in the evolution of new applications was shown and evidence of the importance of peacetime molding and fabrication techniques to quantity production of military items was presented. In this article a few examples of reinforced plastics are given. A good example of the creation of a molded unit with an integral core—in this case balsa wood—is the experimental helicopter blade developed by the USAF Air Materiel Command and the Cornell Aeronautical Laboratory. Tests have proved that the unit is aerodynamically and structurally superior to most conventional types of rotor blades. A big development of the past couple of years is in electrical grade glass-polyester ma-

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AER—Aeronautical Engineering Review, Institute of Aeronautical Sciences, Inc. 2 East 64th St., New York 21, N. Y.

ALL—The Abstract Bulletin, Aluminum Laboratories, Ltd. P. O. Box 84, Kingston, Onatrio, Canada.

AWWA—Journal, American Water Works Association. Amer. Water Works Assoc., 521 Fifth Ave., New York 17, N. Y.

BL—Current Technical Literature, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

BTR—Battelle Technical Review, Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio.

BNF—Bulletin; British Non-Ferrous Metals Research Association. 81-91 Euston St., London NW 1, England.

CALCO—Calco Chemical Division, American Cyanamid Corp. Bound Brook, New Jersey.

CE—Chemical Engineering, McGraw Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

CEC—Consolidated Edison Co. of New York, Inc. 4 Irving Place, New York 3, New York.

EL—Electroplating. 83/85 Udney Park Road, Teddington, Middlesex, England.

EW—Electrical World, McGraw-Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

GPC—General Petroleum Corp. of California. 2525 East 37th St., Los Angeles 11, Calif.

INCO—The International Nickel Co., Inc. 67 Wall Street, New York 5, New York.

IP—Institute of Petroleum, 26 Portland Place, London W.#1, England.

MA—Metallurgical Abstracts, Institute of Metals, London, England. 4 Grosvenor Gardens, London SW 1, England.

MI—Metallurgia Italiana. Associazone Italiana di Metallurgia. Via S. Paola, 10, Milano, Italia.

MR—Metals Review, American Society of Metals. 7301 Euclid Ave., Cleveland 3, Ohio.

NALCO—National Aluminate Corp. 6216 West 66th Place, Chicago 38, Illinois.

NBS—National Bureau of Standards. Supt. of Documents, U. S. Gov't Printing Office, Washington 25, D. C.

NSA—Nuclear Science Abstracts. United States Atomic Energy Commission, Technical Information Division, Oak Ridge, Tenn.

PDA—Prevention Deterioration Abstracts. National Research Council, 2101 Constitution Ave., Washington 25, D. C.

RA—Refrigeration Abstracts, American Society of Refrigeration Engineers. 40 West 40th St., New York 18, N. Y.

RM—Revue de Metallurgie, Paris, France. 5 Cite Pigalle, Paris (9e), France.

RPI—Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries, Research Association of British Paint, Colour & Varnish Manufacturers, London. Waldegrave Rd., Teddington, Middlesex.

TDD—Technical Data Digest, Air Material Command—Technical Service Section, Central Air Documents Office, Wright-Patterson Air Force Base, Dayton, Ohio.

TIME—Transactions of Institute of Marine Engineers. 85 The Minories, London EC 3, England.

UOP—Universal Oil Products. 310 South Michigan Ave., Chicago, Illinois.

ZDA—Zinc Development Association. Lincoln House, Turl Street, Oxford, England.

terials for compression molding purposes. Following this development, conventional high pressure laminators as well as other low pressure laminators have moved into the field. Following these came the development of the dielectric grade molding material made of irregularly chopped glass fibers and polyesters. Another development of military importance in this field—and one which received its main impetus from the civilian market—is the corrugated translucent partition panels. One of the better known and most profitable applications of reinforced plastics wherein glass mat is used with polyesters in compression molding is in the tray and tote box field. This is one spot where preforms could not be made to do the job and where strength of plastic and glass reinforcement alone was not always sufficient for the purpose; metal reinforcement had to be built in. Still another advantage of the glass-reinforced polyester moldings is their acceptance of adhesives and coatings.—TDD.

1.3 Reviews

1.3

The Corrosion Situation: Past, Present and Future. U. R. EVANS. *Chemistry and Industry,* No. 34, 706-711 (1951) Aug. 25.

This paper was delivered at the inaugural meeting of the Corrosion Group of the Society of Chemical Industry. The author stresses the value of research into corrosion problems, and makes a plea for more "corrosionists," with the hope that those who enter industry in this capacity will stay in it long enough for their early experience to be put to good use. Various examples are quoted of the solution of corrosion problems by scientific investigation. One concerns the use of a zinc dust paint to counteract corrosion fatigue and another the use of a zinc nib to apply dilute hydrochloric acid for removing malignant patina from statues, etc., suffering from bronze disease. The nib is connected by a flexible wire to the bronze, and the cell set up prevents chloride ions from diffusing into cracks in the metal.—ZDA.

1.3

Corrosion of Metals. G. T. PEAT. *J. Inst. Production Engrs.,* **30,** No. 2, 55-61 (1951) Feb.

The author defines corrosion and describes galvanic action and the differential aeration theory of U. R. Evans. Graphitic wastage in cast iron and caustic embrittlement in boilers are two particular types of corrosion mentioned in detail and only brief mention is made of metallic and paint coatings.—ZDA.

1.3, 3.6.1, 3.5.6, 5.1

Some Methods of Protection Against Metallic Corrosion. T. A. EVANS. *J. Inst. Production Engrs.,* **30,** No. 2, 62-78 (1951) Feb.

A review of the theoretical aspects of corrosion and of the practical steps which may be taken to retard it. The author explains the principles of electrochemical action and anodic corrosion, the theory of differential aeration and the effect of porosity on metallic corrosion. He describes experiments illustrating the effect of atmospheric impurities and relative humidity on the rate of corrosion. The protective measures mentioned include the use of zinc and cadmium coatings, anodic inhibitors and paint films.—ZDA.

1.3, 5.3.1, 5.4.1

Spotlighting Finishing Progress. ALLEN G. GRAY. *Products Finishing,* **15,** 50, 52, 54, 56, 58, 60, 62, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 90, 92 (1951) Aug.

Presents reviews of the following papers: "Recent Developments on Plating Methods and Equipment," R. B. Saltonstall and John V. Davis; "Factors Affecting Antifouling Paints," A. L. Alexander, R. I. Benemelis, and S. B. Crecelius; "Monel Pickling Equipment Gives Long Service Life" (International Nickel Co.); "Resistance and capacitance Measurements Are Useful in Determining the Corrosion Resistance of Painted Steel," F. Wormwell and D. M. Brasher; and "Smoothing Metal Surfaces by Electroplating Avoid Cold Working Effects," Charles L. Faust.—BLR.

1.3, 8.4.3

Corrosion Fundamentals in Field Application. ALFRED CHATENEVER. *World Oil,* **133,** 194-196+ (1951) July 1.

The relation of fundamental corrosion theory as developed in the research laboratory to actual field practice is clarified to show how complicated studies bring about practical mitigation programs. Chemical and electrical theories of corrosion are briefly discussed, and a possible answer to the pitting problem is presented.—BLR.

1.4 Bibliographies

1.4, 1.6

Bibliographic Survey of Corrosion, 1946-1947. Published by the National Association of Corrosion Engineers, Room 1061. M & M Bldg., Houston, Texas. Publication No. 51-1, 288 pages, copyrighted 1951.

This is a further publication similar to "Bibliographic Survey of Corrosion—1945," published previously. An abstract is provided for each reference. These abstracts were received from various abstracting services which are regular contributors to the journal *Corrosion. Chemical Abstracts, Corrosion and Material Protection, Engineering Index* and *Metals Review* were searched for additional abstracts. The abstracts are arranged according to the November 1st, 1950 revision of the NACE Abstract Filing System Index. Cross references are included at the end of each section. An appendix indicates how journals may be located and the services which do copying work, so that the original references may be obtained. Both author and subjects indices are included.—ALL.

1.5 Directories of Material

1.5, 6.2.1, 1.7.1

Report of Committee A-5 on Corrosion of Iron and Steel. T. R. GALLOWAY, chairman. Am. Soc. Testing Materials, Preprint 4, 1951, 19 pages. (TA401 AM35p.)

Includes report of subcommittee XV on field tests of wire and wire products and proposed tentative specifications for zinc-coated iron or steel chainlink fence fabric galvanized before weaving. Subcommittee report presents data on atmospheric corrosion testing. Materials tests were mostly bare steel and zinc-coated wires and wire products, but copper-covered and lead-coated steel wires and chromium and chromium-nickel steel wires are also included.—BLR.

1.6 Books

1.6, 4.6.1

Water Treatment for Industrial and Other Uses. ESKEL NORDELL. 526 pages. 1951. Reinhold Publishing Corp., New York. (TD34S N75w.)

Discusses impurities in water supplied and how they can be eliminated or reduced to allowable tolerances. Over 1000 analyses are concisely tabulated. Gives water requirements for industrial uses, and current water-treatment practices in various industries. Describes problems and practices relating to boiler feed waters and cooling waters. Processes and equipment are discussed. Chapter bibliographies.—BLR.

1.6, 5.4.5

Glossary of Terms Used in the Paint, Varnish, and Allied Trades. H. W. CHATFIELD. Scott, Greenwood & Co., London, 1951, 200 pp. Price 30/.

This is a reprint, in handy form, of the series originally published in the *Paint, Oil and Colour Journal.* Meanings and definitions of all the most frequent terms currently used in the industries are included, together with information on the nature of many proprietary products in common use. Criticisms may be directed at the brevity of some of the information given, but it is manifestly impossible to give more than an indication of the meanings of such a large number of terms. The author appears to have succeeded in his efforts to include as much relevant information as may be expected in a work of such a general nature.—RPI.

1.7 Organized Studies

1.7.1

Sixteen Inter-Society Corrosion Committee Members Report on Activities During 1950. (U. S.) Inter-Society Corrosion Committee. *Corrosion,* **7,** No. 5, 14+ (1951) May.

The Inter-Society Corrosion Committee consists of delegates appointed by the technical societies and Government agencies of North America working in the field of corrosion. The present publication includes short reports of corrosion research in progress at the Federation of Paint and Varnish Production Clubs; Office of Naval Research; National Research Council (Canada); American Electroplaters' Society; National Association of Corrosion Engineers; American Society for Testing Materials; Electrochemical Society; National Bureau of Standards; Association of American Railroads; and the National Research Council (U.S.A.).—BNF.

1.7.1

Paint and Coating Research at the Battelle Memorial Institute. *Paint Manufacture,* **21,** 61-63 (1951) Feb.

Describes and illustrates facilities and organization for the above.—BLR.

1.7.1, 6.4.2, 8.9.5

Engineering Group Meets at Corrosion Testing Station. *Marine Eng. & Shipping Rev.,* **56,** No. 8, 48-49 (1951) Aug.

The sixth annual meeting of 80 marine and powerplant engineers was held recently at the Harbor Island Corrosion Testing Station, Wrightsville Beach, N. C. The following subjects were considered: 1. effects of composition and heat

treatment on the behavior of aluminum alloys in sea water and marine atmospheres; 2. galvanic corrosion of aluminum when in contact with other metals and alloys in sea water and marine atmospheres; 3. effects of marine organisms on corrosion of aluminum; 4. the effect on aluminum of effective copper-base antifouling paints; 5. the effect of velocity on the corrosion or erosion of aluminum alloys; 6. marine corrosion and the use of light alloys in superstructure construction on ships.—ALL.

1.7.1, 2.4.3, 2.1.2

The Possibilities of Radiocrystallography as a Method of Non-Destructive Control. (In French.) A. GUINIER. *Metaux: Corrosion-Industries*, **26**, 131-134 (1951) Mar.

Outlines and discusses the above. Diagram shows a punched card designed for indexing the crystallographic properties of materials.—BLR.

1.8 Personalities

1.8, 1.3, 8.9.5

Sir Charles Parsons and Cavitation. 1950 Parsons Memorial Lecture, read by Prof. L. C. Burrill, at a meeting of The Institute of Marine Engineers, 22nd May 1951. *Trans. Inst. Marine Engrs.*, **63**, No. 8 (1951).

The 1950 Parsons Memorial Lecture entitled "Sir Charles Parsons and Cavitation" describes the pioneer work of Sir Charles Parsons in connection with the problem of "cavitation" in marine propellers. Early letters reveal the difficulties which he encountered in connection with the trials of the Turbinia. The vessel was first fitted with a single shaft, and the results obtained were extremely disappointing due to losses in the propeller. Many propeller arrangements were tried and it was not until after three years of experimenting that the final result was achieved, with nine propellers fitted on three shafts. The first cavitation experiments carried out by Sir Charles in 1895 are described, including the making of the first small cavitation tunnel, in which quite good photographs were obtained showing the nature of the phenomenon. Following a period of development during which the size of turbine installations for marine purposes increased considerably, the first large cavitation tunnel was built at Wallsend in 1910. Details are given of hitherto unpublished work carried out in this tunnel, with systematically varied model propellers, 12 inch in diameter, and the method of presentation adopted by Sir Charles in connection with these tests is discussed. There follows a short description of the work which Sir Charles carried out to prove that the erosive action of cavitation was due to the collapse of the bubbles on the blades of propellers, and was mechanical in nature, not chemical; and details are given of some tests in the Wallsend Tunnel in connection with propellers for high-powered Atlantic liners, showing the correspondence obtained between the photographs taken of the model propellers working in the tunnel under vacuum, and the erosion which occurred in service. Finally there is reviewed briefly the modern approach to the problem of cavitation, and the developments which have taken place since

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the time of Sir Charles Parsons' early work, and the author shows that the main conclusions at which he arrived are still valid today, although slightly modified and extended in the light of recent theoretical and experimental work.

2. TESTING

2.1 General

2.1.1, 6.2.5

Statistical Study of the Corrosion-Resistance of 18 Chromium—8 Nickel Steel in Acid Copper Sulphate. J. Bleton, J. Blanot and P. Bastien. *Rev. Met.*, **48**, 525-536 (1951) July.

Tests on samples of 91 melts in order to ascertain effects of variations in carbon, nickel and chromium contents. Carbon varied between 0.025 and 0.080, chromium between 18 and 20, and nickel between 9.5 and 11.5 percent. Decisive factors in estimating probable behavior were found to be chromium and carbon contents.—INCO.

2.1.1, 6.3.1, 2.3.5

The Time Curve of the Electrical Potential of Several Metals After Abrading Them in Vacuum. (In German.) F. Fianda and E. Lange. *Z. Elektrochem.*, **55**, 237-244 (1951) Apr.

Experimental results show that work function of freshly abraded metals changes rapidly. The main cause of this phenomenon is assumed to be chemisorption of oxygen. Metals investigated were silver, copper, tin, zinc, cadmium, lead, aluminum and magnesium. 50 references.—MR.

2.2 On Location Tests

2.2.4, 4.2.5

Report of Laboratory Tests to Determine any Adverse Effect of High or Low Humidity on Materials and Equipment Found Aboard U. S. Naval Vessels. U. S. Naval Base, Industrial Test Laboratory. Report 3014-A, 148 pp.

The results of submitting 230 items e.g., electrical parts, metal parts, paints, optical instruments, to various relative humidities on board naval vessels, in the hold of a ship and in shipyard buildings are given. Materials and equipment stored at 30-35 percent R.H. showed little or no deterioration.—RPI.

2.3 Laboratory Methods

2.3.2, 2.4.2

Durability Testing of Protective Coatings. U. S. National Bureau of Standards. *Engineer*, **191**, No. 4961, 268 (1951) Feb. 23.

Brief description of testing machine constructed by the Building Technology Division of the U. S. National Bureau of Standards for Subjecting specimens to strictly controlled cycles of artificial sunlight, heat and water.—BNF.

2.3.2, 5.4.1, 5.3.1, 4.2.4

Method for Corrosion-Testing of Metallic and Non-Metallic Protective Coatings in Synthetic Industrial Atmospheres. W. Kesternich. *Stahl u. Eisen*, **71**, 587-588 (1951) May 24.

Simplified rapid method based on condensation method of testing in atmosphere of carbon dioxide, sulfur dioxide with water. Full description of apparatus and testing technique is given. Reference is made to tests on bright chromium and nickel coatings, in which former remained bright, while nickel was attacked; in ordinary atmospheric-testing conditions, nickel remained unattacked for several weeks. Method is said to be in use for atmospheric testing of unprotected materials.—INCO.

2.3.2, 5.4.5, 8.9.1

Methods of Evaluating Aircraft Primers. E. T. Nelson. *Org. Finishing*, **12**, No. 2, 12-17 (1951) Feb.

The author presents a brief outline of the methods used by the Douglas Aircraft Co., for evaluating aircraft primers and outlines some of the special properties of a primer that are necessary to satisfy the company's production and service requirements. Aircraft primers are used as shop protective coatings on detail parts and subassemblies, insulation between dissimilar metals, general corrosion inhibition, primer coats for lacquer or enamel, and even as a final color finish in certain cases of some military aircraft. They must be capable of being applied to such materials as aluminum alloys, bare or cadmium-plated steel, magnesium alloys, and corrosion resistant steel. The primers are subjected to tests outlined in the Air Force-Navy Aeronautical Specification AN-P-656. These tests are outlined in the paper.

Tests for physical properties include: appearance, odor and skinning; weight per gallon; moisture content; setting; viscosity and stability. Tests for film properties include: working properties, surface appearance, and color; drying time and stacking test; flexibility, and metal anchorage and coating anchorage. Tests for resistance properties include: lacquer resistance and primer absorption; water and hydrocarbon resistance; weather resistance and corrosion inhibition, and resistance to scalants. The author states that new tests are currently being devised to check the resistance of zinc chromate and other-primers to certain nonflammable hydraulic oils, hydrogen peroxide, and other propellants. A discussion follows.

2.3.4, 4.3.2, 6.3.1

A Standard Laboratory Corrosion Test for Metals in Phosphoric-Acid Service. H. F. Ebling and M. A. Scheil. *Trans. Am. Soc. Mech. Engrs.*, **73**, 975-987 (1951) Oct.

A standard laboratory-test procedure for corrosion in phosphoric acid is proposed, using c.p. 85% orthophosphoric acid. The specimen is put into cold acid; the acid is brought to a boil and held there for 24 hours. A formula is given for calculation of the corrosion rate. Test results were found to be reproducible within ±10% when good laboratory technique and equipment were used. No intergranular type of attack was observed on ELC Type 316 and 317 alloys. Copper in the 316 alloy or in the solution was shown to be a powerful corrosion-inhibiting agent. Silver acted similarly but cadmium and tin did not. The relation between the laboratory test and field experience is presented and illustrated. A table of laboratory corrosion-test results is presented as a guide in selecting metals for phosphoric-acid service.—NSA.

2.3.5, 3.2.2

Susceptibility of Steels to Hydrogen Blistering May Be Determined. *Petroleum Processing*, **6**, 879-881 (1951) Aug.

The susceptibility of steels to hydrogen blistering may be determined by an electrolytic preinstallation test originally developed to evaluate the suitability of steels for zinc plating. The electrolyte solution contains 15-20 percent by weight sulfuric acid. Descaled specimens are made from the cathode in the electrolyte and the test is run for six hours at a current density of 10 amps/sq. ft., the temperature being maintained at 100-200° F. A material subject to severe blistering and fissuring under these conditions would be considered unsuitable for zinc plating operations, and possibly for refinery service also.

2.3.5, 5.3.4, 3.4.6

Aging Effects in Copper-Lead Alloy Plating Solutions of the Cyanide-Tartrade Type. Nelson W. Hovey, Albertine Krohn, and A. L. Ferguson. *J. Electrochem. Soc.*, **98**, 155-159 (1951) Apr.

Above were studied during a 50-day period by measurements of single-metal potentials, static and dynamic alloy potentials, oxidation-reduction potentials, alloy compositions, and absorption spectra of the plating solutions. Similar measurements on a portion of the solution stored under nitrogen established atmospheric oxidation as the cause of aging.—BLR.

2.3.5, 8.9.3

Corrosion and Its Control—Installation and Use of Test Leads on Pipe Lines. M. E. Parker. *Oil Gas J.*, **50**, No. 7, 339 (1951) June 21.

Test leads are installed in pairs so they can measure both pipe-to-soil potential, and line current. The distance between the 2 leads should be 3.98 times the weight of the pipe in lbs./ft. If leads are installed on existing pipe lines, they should be attached by thermite welding and the weld carefully coated. Exact methods of installation are given.—INCO.

2.3.6, 6.3.6, 3.7.4, 3.4.6

Determination by Interference Coloration or by Polarized Light of the Oxidation-Rate of Certain Faces of a Copper Monocrystal. (In French.) Allen T. Gwathmey and Frederick W. Young. *Rev. met.*, **48**, 434-440 (1951) June.

Presents an experimental method for studying the above. Results obtained confirm the principle that rate of oxidation depends for the most part on type of crystalline face which makes up the exposed surface. Greatest source of error in above experiments lies in preparation of of surface, which must be smooth and not cold-worked. Data are tabulated and graphed. 10 references.—BLR.

2.3.6

Rust and its Morphology. (In German.) O. Gerhardt. *Werkstoffe u. Korrosion*, **2**, No. 4, 129-131 (1951) April.

Author discusses microscopic observation of rust which he thinks throws a useful light on various problems of corrosion.

Formation, transformation and structures of surface and "under paint" iron rust. Includes photomicrographs.

2.3.7, 2.1.2

Methods of High Temperature Oxidation Testing and Evaluation of Observa-

tions. C. WAGNER. (MIT). Paper before ASM, 32nd Natl. Metal Congress & Exposition, Chicago, Oct. 23-27, 1950. ASM, "High Temperature Properties of Metals," 1951, 93-132.

The oxidation of metals to metal oxides is the most important cause of high temperature corrosion. Experimental methods for kinetic investigations and to determine the structure of the oxide layers and the rate laws for the oxidation of metals are discussed. When platinum-nickel alloys are oxidized, only nickel-mono-oxide is formed by the outward diffusion of nickel. Only nickel mono-oxide is formed when nickel-copper alloys containing 10-90 nickel were oxidized at 800 degrees C (1470 degrees F) under oxygen pressure of 1 mm. mercury. At atmospheric pressure and 800-1000 degrees C, alloys containing less than 20 copper, bal nickel, the copper was oxidized at the same rate as nickel, but at higher copper content a much higher oxidation rate was observed and both nickel mono-oxide and copper oxygen were formed, and the oxidation rate exceeded that of pure nickel. The rate of oxidation is directly correlated with the ionic conductivity of the oxide phases of both metals. The characteristics of any binary alloy may be determined by nucleation and phase boundary reactions. The change in the oxidation rate of nickel with varying amounts of chromium (0-3.0%) and of manganese (0-3.0%) at 1000 degrees C are given. The migration mechanism of oxides of nickel, iron, copper, chromium, cobalt are explained. Rapid oxidation of Armco steel and stainless steels was observed above 600 degrees C when they become contaminated at the surface with oxides of bismuth, potassium, vanadium or molybdenum. 89 references.—INCO.

2.3.7, 2.4.2

Hot Fatigue Testing. H. E. GRESHAM AND B. HALL. Iron and Steel Institute. "Symposium on High Temperature Steels and Alloys for Gas Turbines," 1951, pp. 181-185. (TN673 Ir6s).

General details of the construction of a simple single-point loading fatigue machine are given and the construction of the furnace and the temperature measurement are discussed. The adaptability of the apparatus is illustrated by its use for corrosion-fatigue testing with corrosion media in the form of gases, solids, or as a spray. Specific research items in which this apparatus has proved useful are discussed and illustrations are given of a few of the more interesting results. —BLR.

2.3.7, 6.3.11

Measuring the Oxide Film on Platinum. (In German.) H. GRUBITSCH, *Werkstoffe u. Korrosion*, **2**, 85-89 (1951) Mar.

Criticizes Todt's method for determining the above. Shows that the amount of oxide on the platinum surface is proportional to the absolute, not the active, surface.—BLR.

2.3.7, 7.1

Laboratory Evaluation of Materials for Marine Propulsion Gears. M. R. GROSS. U. S. Navy Eng'g. Experiment Sta. Paper before ASTM, 54th Ann. Mtg., June 18-22, 1951. Am. Soc. Testing Materials, Preprint No. 38, June 1951, 16 pp.

Tests to evaluate the pitting resistance and root fatigue strength of materials for marine gear applications are reported. By contact roller test machines, pitting

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	Preparation for Painting	"ALODINE" "DURIDINE" "DEOXIDINE"
	Protection from Corrosion	"ALODINE"
BRASS	*Brightening*	"ACP BRIGHT DIP"
	Cleaning	"DEOXIDINE" "DURIDINE" "ACP RIDOLINES AND RIDOSOLS"
	Cleaning for Painting	"DEOXIDINE" "CUPROTEK
	Corrosion Prevention	"CUPROTEK"
	Soldering Flux	"FLOSOL"
COPPER, BERYLLIUM, AND COPPER ALLOYS	*Brightening*	"ACP BRIGHT DIP"
	Cleaning	"DEOXIDINE" "DURIDINE" "ACP RIDOLINES AND RIDOSOLS"
	Cleaning for Painting	"DEOXIDINE" "CUPROTEK"
	Coating Steel with Copper	"CUPRODINE"
	Corrosion Prevention	"CUPROTEK"
	Scale Modification	"RIDOXINE"
	Soldering Flux	"FLOSOL"
	Stripping Copper Coatings	"ACP COPPER STRIPPING SOLUTION"
GALVANIZED IRON, ZINC, AND CADMIUM	*Cleaning*	"DURIDINE" "ACP RIDOLINES AND RIDOSOLS"
	Corrosion Proofing	"ZINODINE"
	Paint Bonding	"ZINODINE"
	Phosphate Coating, in Preparation for Painting	"LITHOFORM"
	Soldering Flux	"FLOSOL"
IRON AND STEEL	*Chromate Coating, in Preparation for Painting*	"CROMODINE"
	Cleaning	"ACP RIDOLINES AND RIDOSOLS"
	Cleaning for Painting	"DEOXIDINE" "DURIDINE"
	Coating with Copper	"CUPRODINE"
	Drawing and Extrusion	"GRANODRAW"
	Paint Bonding	"CROMODINE" "DURIDINE" "GRANODINE" "PERMADINE" "THERMOIL-GRANODINE"
	Paint Stripping	"CAUSTIC SODA AND SOLVENT NO. 3"
	Phosphate Coating, in Preparation for Painting	"DURIDINE" "GRANODINE" "PERMADINE" "THERMOIL-GRANODINE"
	Phosphate Coating, to Protect Friction Surfaces	"THERMOIL-GRANODINE"
	Pickling with Inhibited Acids	"RODINE"
	Rust Prevention for Unpainted Iron	"PEROLINE"
	Rust Proofing	"PERMADINE" "THERMOIL-GRANODINE"
	Rust Removal—Brush, Dip, or Spray	"DEOXIDINE"
	Soldering Flux	"FLOSOL"
MAGNESIUM	*Cleaning*	"DURIDINE" "ACP RIDOLINES AND RIDOSOLS"
	Pickling	"RODINE (M-200)"
STAINLESS STEEL	*Cleaning*	"DEOXIDINE"
	Coating with Copper	"CUPRODINE"
	Pickle Polishing	"RODINE"
	Soldering Flux	"FLOSOL"

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limits were determined for the following materials: 2.5 nickel, 0.5 molybdenum steel; 2.5 nickel, 1.0 chromium, 0.5 molybdenum, 0.25 vanadium steel; 4.75 chromium, 0.19 nickel, 0.48 molybdenum steel; SAE 4615 steel; NE 8615 steel; aluminum alloys; beryllium-copper; Dowmetal C; and 5 plastic base materials. The "simulated gear tooth fatigue test" was developed to evaluate the root fatigue strength of materials under reversed bending stresses. The effect of hardening treatments, root radii and surface finish and treatments on the endurance limit of the root area was determined. Hardened copper-beryllium alloy has the highest resistance to pitting of any of the nonferrous materials tested.—INCO.

2.3.7, 2.4.4

G.E.C. Layer Thickness Meter. *Mech. World Eng. Record,* **129,** No. 3363, 616 (1951) June 29.

This magnetic instrument gives a rapid determination of the thickness of paint, plastic, or non-ferrous metal coatings on iron or steel. It is a pocket-sized instrument and is available for thicknesses ranging up to 5, 10, or 30 thousandths of an inch.—ZDA.

2.3.7, 5.4.5, 6.3.14

Methods of Testing Lacquer Coatings on Tinplate. W. E. HOARE. *Sheet Metal Inds.,* **28,** No. 287, 231-233, 244 (1951).

Methods of testing stoved or air-dried lacquer films on tinplate are described. The main uses of such lacquers are: 1) protection of exterior surfaces, 2) protection of interior surfaces, 3) protection of contents of a container from metal contamination, and 4) protection of decoration or legend. The types of lacquer and the required properties are briefly discussed. The main tests are: a) continuity tests, b) film weight or thickness-of-coating tests, c) adhesion tests, d) bend tests, and e) abrasion and hardness tests. 20 references.—MA.

2.3.9

Radiography With Cobalt 60. ADAIR MORROSION. *Non-Destructive Testing,* **9,** 14-22 (1951) Spring.

Shows that Co^{60} can readily be substituted for radium in industrial radiography. Advantages are cited; data for steel are charted. 10 references.—BLR.

2.3.9, 2.4.3

Inspection, Processing, and Manufacturing Control of Metals by Ultrasonic Methods. CARLTON H. HASTINGS AND SEYMOUR W. CARTER. A.S.T.M. Symposium on Ultrasonic Testing, 1951, 14-16.

The following matters are discussed in much detail: 1) types of ultrasonic generators; 2) the use of ultrasonics to produce grain-size refinement in as-cast metals (this has been shown to be effective in the cases of zinc, aluminum, tin, cadmium, and antimony); 3) acceleration of solidification by ultrasonics; 4) heat-treating; 5) removing oxide films from metals in plating, bonding, and tinning processes; 6) the detection of discontinuities; 7) principles of testing; 8) the introduction of ultrasonics into a material; 9) methods of detecting ultrasonics which have traversed a material; 10) instrumentation both simple and advanced; 11) requirements for visual presentation of results; 12) the inspection of strips, slabs, plates, bars and welds; 13) thickness measurement; and 14) a suggested program of investigation, e.g. the detection of inclusions, segregations, and the use of surface waves for detecting surface cracks, and the effects of grain-size and metallographic phases on ultrasonic wave propagation. 342 references.—MA.

2.3.9, 2.4.3

An Evaluation of Radiography, with Particular Emphasis on Detection Methods. CARLTON H. HASTINGS. *A.S.T.M. Bull,* No. 172, 66-70 (1951).

Past trends of development, the present status, and future objectives of the radiographic method of non-destructive testing are discussed. It is considered that improvements are desirable in the quality of radiographs and in the speed with which inspection data are obtained. It is suggested that techniques employing television or other electronic principles show promise for attaining these ends, and could eventually lead to automatic or semi-automatic inspection and control of products.—MA.

2.3.9, 3.2.2, 8.4.3

Easily Made Test Probe for Hydrogen Attack. *Petroleum Processing,* **6,** 877, 879 (1951) Aug.

A standard test probe for determining conditions which promote hydrogen blistering of low carbon steels in refinery process equipment, developed by Shell Oil Co., consists of a thin-walled section of carbon steel tubing fitted over a solid steel rod. A measurable change in pressure with only a small accumulation of hydrogen is obtained. The annular space between tubing and rod communicates with a pressure gauge or continuous recorder. Construction details are illustrated.

2.3.9, 3.4.6

The Sorption of Gases on Metals at Room Temperature. A. L. MCCLELLAN AND NORMAN HACKERMAN. *J. Phys. and Colloid Chem.,* **55,** 374-382 (1951) Mar.

Isotherms for sorption of oxygen, chlorine, nitrogen monoxide and dioxide at 30°C. on unreduced and reduced surfaces of S.A.E. 1020 steel, 18-8 steel and pure chromium powders, were determined with quartz-spiral spring balance. Results are compared with those of other investigators. Each of the gases was picked up by the metals in following decreasing order; steel, 18-8, chromium. Thickness of oxide films on steel is discussed.—INCO.

2.3.9, 3.4.6

Study of Selective Oxidation of Iron-Nickel Alloys by X-Ray Diffraction. (In French.) JEAN MOREAU AND JACQUES BENARD. *Comptes rend.,* **232,** 1842-1843 (1951) May 16; *Metals Rev.,* **24,** No. 8, 39 (1951) Aug.

Describes a method for determining the variation in composition of very thin metallic layers. By this method, composition of the metallic phase in contact with the oxide was determined for alloys containing 5, 10, 20, and 30 percent nickel at 850, 950, and 1050°C. Results are charted and discussed.—BLR.

2.3.9, 3.7.3

Radiographic Investigation of Weldings: An Attempt of Quantitative Valuation of the Defects. O. MASI. *Met Ital.* **43,** 261-269 (1951).

The method proposed by the author consists essentially of the determination of the resistant thickness, in welded, traction test bars, carried out by photometric measurings and after having calibrated the film with a diagram D=f (s) deduced by measuring the photographic densities D obtained for the different thicknesses of a calibrated piece. The article refers to three different cases corresponding to typical defects in the weldings (scarce penetration, porosity, inclusions). The measures have been carried out by photometric readings and also by microphotometric tests; the concordance of the two measuring systems is good and also satisfactory is the concordance of the strength values calculated with the experimental values.

The author trusts that the systematic phase of the research may be laid out in collaboration among the various specialized laboratories.—MI.

2.3.9

Progress in Gamma Radiography. *Atomics,* **2,** No .4, 112-118 (1951).

Supplies of cobalt (Co^{60}), tantalum (Ta^{182}), and iridium (Ir^{192}) are now available, which are suitable for the nondestructive inspection of castings and welds. Co^{60} and Ta^{182} are suitable for the penetration of steel 2-6 inches thick, and Ir^{192} for steel of thickness 0.5-2.5 inches and for short-focus work with pipes and the radiography of small metallic objects. Supply details and an exposure-times chart are given. A new X-ray film, 2 to 3 times as fast as films hitherto supplied, is now available. New apparatus for the storage of active materials, for exposure of sources for radiography and for radiation monitoring are briefly described.—MA.

2.3.9, 2.4.3

Modern Non-Destructive Methods for Detecting Faults in Castings. BASTIEN. *Usine nouvelle,* **7,** No. 6, 21 (1951).

A brief survey of modern methods for the X-ray radiographic examination of metals, with particular reference to the examination of welds and castings for faults.—MA.

2.3.9, 2.4.3

Radiographic Inspection of Steel Castings. J. M. FLANAGAN. Ordnance, Army Dept. Paper before Instruments Soc. Amer., "Instrumentation for the Iron & Steel Ind." Conf., CIT & Pitt. Sect., Pittsburgh, Mar. 28 & 29, 1951. *Instruments,* **24,** No. 6, 655, 688-689 (1951) June.

A history is presented of radiographic inspection and X-ray, gamma ray and the betatron are compared. The importance and use of contracts and specifications in radiographic inspection are explained.—INCO.

2.3.9, 2.4.3

Metal Wall Thickness Measurement from One Side by the Ultrasonic Method. N. G. BRANSON. Branson Instruments, Inc. Paper, AIEE Winter Meeting, N. Y., Jan. 22-26, 1951. *Elec. Eng.,* **70,** No. 7, 619-623 (1951) July.

Ultrasonic resonance methods measure metal wall thickness and also can be used for flaw detection. X-cut crystals are used and the highest frequency at which they are driven should be below the natural frequency of the crystal itself to avoid resonance. The selection of quartz crystals and range, accuracy and limitations of the method are discussed.—INCO.

2.3.9, 3.5.3

Resistance of Materials to Destructive Action of Cavitation is Being Stud-

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ied at Allis-Chalmers Manufacturing Co. With Accelerated Test Apparatus. *Machine Design*, **21**, 105 (1949) June.

A description of testing method follows: A small sample or button of the material to be tested is attached to the end of a nickel rod which vibrates longitudinally in the electronically induced alternating magnetic field. The rod is so positioned that the test specimen is slightly under the surface of a constant-temperature distilled water bath, causing an accelerated formation of cavitation bubbles on the surface of the sample. Weight loss of the specimens during two hours of test, equivalent to years of service, is a measure of the pitting which has taken place. Among materials tested are stainless steels, bronzes, sprayed metals, several of the superalloys and rubber coatings.

2.3.9, 3.7.4, 3.7.3

Radioactive Isotopes in Industry. I.—Metallurgy. *Atomics*, **2**, No. 2, 39-42 (1951).

Radioactive Fe (Fe^{55} or Fe^{59}) has been used to determine the diffusion rates that enter into such phenomena as annealing, hardening recrystallization grain-growth, and high-temperature behavior in steel. The diffusion of carbon in α-iron has been studied with radioactive carbon (C^{14}) at temperatures below 725 degrees C. Radioactive zinc and copper have been used to study self-diffusion in stressed metals. Radioactive tungsten (W^{185}) has been used to locate the tungsten in a 70:25:5 nickel-chromium-tungsten alloy; it was found in the dendrites. In a cobalt-base alloy it was shown that the tungsten is generally associated with the intermetallic compounds and solid solutions between the dendrites. A few tenths percent of aluminum present in silicon rectifiers are located by irradiation with neutrons; radioactive phosphorus has been used to measure and locate phosphorus in alloys. Radioactive iron and other radioactive isotopes have been used to study corrosion problems, metal-cleaning processes, and in the study of friction between piston-rings and radioactive chromium-plated surfaces; a very much smaller amount of worn metal can be detected than with conventional techniques. Factory-scale investigations carried out by radioactive-tracer technique include a study of gas velocities and times of contact between gases and solids in blast furnaces and a study of the distribution of pyritic and organic sulfur present in coal for blast-furnace coke. The ratio of pyritic to organic sulfur in coal does not influence the sulfur content of the finished coke. It is suggested that the flow of metal during extrusion, casting or forging be studied by the new tracer technique.—MA.

2.3.9, 3.8.4

Study of Thin Adsorption Layers by Means of Radioactive Tracers. (In French.) Rene Bernard, Francois Davoine, and Jean Hirtz. *Compt. Rend.*, **232**, 1826-1828 (1951) May 16.

Describes a method of accounting for solid-liquid adhesion in terms of an adsorption film on the surface of the solid.—BLR.

2.3.9, 5.4.1, 5.8.1, 5.5.1

Tracer Method for Evaluating Rust Preventatives. Stanley L. Eisler. *Nucleonics*, **8**, 76-79 (1951) May.

Describes above method which has overcome the shortcomings of the testing procedures used to evaluate these compounds during U. S. Army procurement.

A test panel is immersed in water containing S^{35} labelled Na_2SO_4. After draining, the panel is immersed in the rust preventive and the remaining water on the surface of the panel is measured by the S^{35} activity.

2.3.9, 6.2.2, 5.9.2

X-Ray Diffraction Study of the Oxidation Characteristics of Nickel Pickled Sheet Iron as Related to Enamel Adherence. G. S. Douglas and J. M. Zander. *Better Enamelling*, **22**, No. 2, 8-12+ (1951); *J. Am. Ceramic Soc.*, **34**, 52-59 (1951) Feb.

Nickel pickling reduces the amount of oxide formed under the enamel, causing a corresponding reduction in the time for the complete removal of the oxide, so allowing adherence to be developed in a shorter time or at a lower temperature.—EL.

2.4 Instrumentation

2.4.2

Study of Corrosion Phenomena. *Engineers' Digest* (England), **12**, No. 7, 208 (1951) July.

To facilitate the evaluation of the effects of corrosive solutions, a method has been evolved which is similar to television scanning and permits detection, study, recording and analysis of corrosion phenomena. This method of observation, is based upon the fact that corrosion is caused by thousands of local cells formed on the surface affected. These cells are similar to microscopic galvanic batteries. By studying the action of these cells, much information regarding the fundamental nature of the corrosion phenomena can be obtained. In the scanning device employed, the laboratory example on which corrosion occurs is a metal cylinder. This cylinder is dipped in some corrosive solution such as sea water, rotated several hundred times a minute, and scanned with a stationary probe electrode. The probe electrode, which is a plastic arm containing eleven silver wires, is placed about 0.02 inch away from the wetted cylinder, so that it can pick up the minute electrical currents accompanying the corrosion process. These currents are amplified electronically and visually observed, on an oscilloscope screen or photographed for later analysis. A particular advantage of this method is that it permits easier and faster study of the entire surface of a corrosion sample. The new technique can be used for investigations of cathodic protection, corrosion inhibitors, stress corrosion and in fundamental corrosion studies.—ALL.

2.4.2, 8.9.3

Corrosion Instruments, M. E. Parker. *Oil Gas J.*, **50**, Nos. 14, 15, 16, pages 108, 136, 163 (1951) Aug. 9, 16, 23.

There are 3 major systems of selecting the group of instruments to be used by the corrosion engineer; that in which the basic instrument is the potentiometer; the system employing a single multipurpose instrument; and that using a variety of special-purpose instruments. For pipe-to-soil surveys, the potentiometer and potentiometer-voltmeter are used. Advantages and disadvantages for each system are discussed. Diagrams are included.—INCO.

2.4.3, 1.2.2

Symposium on the Role of Non-Destructive Testing in the Economics of Production. 157 pages, 1951. American Society for Testing Materials. Special Technical Publication 112.

Includes following papers: 1) A Basic Guide for Management's Choice of Non-Destructive Test, Robert C. McMaster and Samuel A. Wenk; 2) Discontinuities in Cast and Wrought Products That Can Be Revealed by Non-Destructive Tests, Kent R. Van Horn; 3) Role of Non-Destructive Testing in the Economics of Castings, John W. Juppenlatz; 4) Economics and Practical Application of Cobalt 60 in the Radiographic Inspection of Steel Weldments, W. L. Schwinn; 5) Economics of Wrought Steel Inspection, C. D. Moriarty; and 6) Management's Responsibility for Insistence on Non-Destructive Testing in the Development of New Engineering Products and Processes," L. W. Ball. Includes introduction by H. H. Lester.—BLR.

2.4.3, 2.3.9

Improvements in the Design of Ultrasonic Lamination Detection Equipment. H. R. Clayton and R. S. Young. *J. Sci. Instruments* (England) **28**, No. 5, 129-132 (1951) May.

The development of an apparatus for the detection of lamination on aluminum blanks is described. The apparatus is a modification of Sokolov's, which depended upon the fact that ultrasonic waves are reflected at the air interface of a lamination. Its disadvantage was that, with certain thicknesses of plate, effects due to the formation of standing sound waves in the path of the beam are liable to produce spurious indications; this happens when the thickness of a test piece is equal to an odd number of quarter wave lengths of sound in the material. This is overcome by energizing the transmitter crystal by a wide band of ultrasonic frequencies and by providing a receiver capable of detecting all the frequencies transmitted. Details of the circuits and tubes are given and diagrammed. Tests have shown that a defect of less than ¾-inch diameter can be detected and that the contours of a lamination can be traced with satisfactory accuracy. The thickness of the material is independent of the results since the transmission of the ultrasonic energy is relatively constant.—ALL.

2.4.3, 2.3.9, 7.2

Magnetic Particle Inspection of Welded Pipe and Tubing. J. E. Clarke, R. A. Peterson, and T. J. Dunsheath. *Non-Destructive Testing*, **9**, 7-13 (1951) Spring.

An illustrated description of above process and its application.—BLR.

2.4.3, 6.2.1

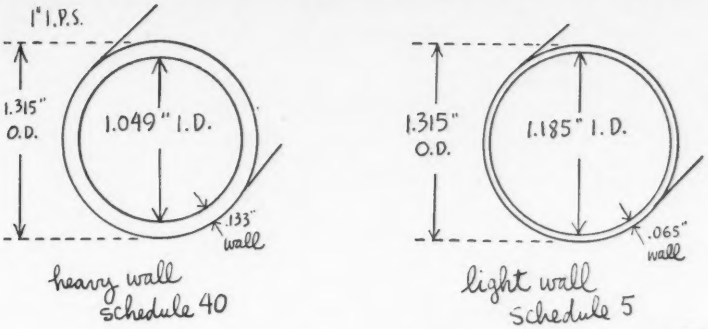
New Methods of Non-Destructive Testing of Steels. F. Forster. *Berg. u. huttenmann. Monatsh. montan. Hochschule Leoben* (Vienna), **95**, No. 12, 284-291 (1950) Dec. (In German).

Describes in general terms various instruments, mainly author's own, for crack detection of steel parts and sorting according to hardness. 10 references to other work.—BNF.

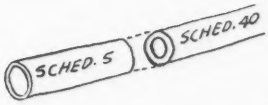
2.4.3

Ultrasonics in the Heavy Forging Industry. James C. Hartley. A.S.T.M. Sym-

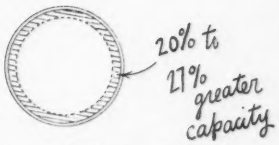
here's what you gain with stainless schedule 5 pipe



You save money. Schedule 5 pipe costs about half as much per foot as Schedule 40.



Schedule 5 has the same O.D. as Schedules 10, 40 and 80 —for hook-up with existing lines as well as for new installations.



Its larger I.D. increases flow and capacity in pipelines, exchangers and other equipment.

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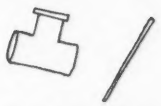
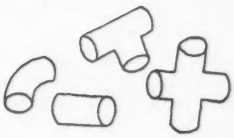


You can save substantially on valves, fittings, weld rods, etc., because smaller O.D. material can frequently be used. Tubing sizes can now be replaced with light wall pipe . . . for ready hook-up with standard valves, pumps, and other equipment normally manufactured in pipe sizes.



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posium on Ultrasonic Testing, 1951, 72-83.

Certain materials, such as the superalloys used for high-temperature service in gas turbines and jet engines, are very suitable for the application of ultrasonic testing to ascertain whether satisfactory refinement by forging has been effected. If it could be established by periodic inspection by ultrasonic methods, that certain known defects of forgings do not become more serious when subjected to stress conditions of a particular kind, the whole concept of quality control would be enlarged, and a better understanding established between manufacturer and customer. The application of ultrasonic testing in the heavy forging industry is briefly and very interestingly reviewed and illustrated.—MA.

2.4.3, 1.3

Non-Destructive Testing of Materials in Austria. (In German.) H. KRAINER. *Metall*, **5,** No. 1/2, 18-20 (1951) Jan.

Reviews developments in spot testing, radiography and magnetic methods. 7 references.—BNF.

2.4.3, 2.3.6

New Magnetic Particle Testing Technique Speeds Inspections of Ferrous Parts. S. G. KELLEY, JR. *Materials and Methods*, **33,** No. 6, 66-68 (1951) June.

A new technique of magnetic particle inspection known as Duovec which enables ferrous parts to be inspected for surface defects in all directions in one operation, is not only considerably faster than the conventional technique, but in many cases has improved sensitivity. This article offers a thorough discussion of the method: its capabilities, limitations, and typical applications.—TDD.

2.4.3, 2.3.6

Nondestructive Testing of Materials. Study of Liquation. (In French.) H. DE LEIRIS. *Metaux: Corrosion-Industries*, **26,** 22-28 (1951) Jan.

Describes method in which drops of liquids based on tetralin, propyl alcohol, or xylene, are placed on the surfaces of materials to be examined. Appearance of the drops is then examined under the microscope, revealing the location and character of surface defects. Illustrated.

2.4.3, 2.3.7

Measurement of the Thickness of Thin Films by Multiple Beam Interferometry. O. S. HEAVENS. *Proc. Physical Society, Section B* (England), **64,** Part 5, No. 377B, 419-425 (1951) May 1.

The method of measuring the thickness of thin films by multiple-beam Fizeau fringes has been studied in order to assess the accuracy attainable. The small-scale irregularities on the surfaces of optical flats and other optically worked glass have been studied by multiple-beam methods. Thickness measurements have been made on films of silver and lithium fluoride with several different metals, such as aluminum, nickel, tin, and copper, as reflecting layers. The measurements cover the range 120 Å to 1500 Å. The results for the different reflecting layers show agreement to within the observational error, provided that measurements are made within a short time of preparation of the films. With silver as the reflecting layer an accuracy of ± 10 Å can be expected if suitable precautions are taken.—ALL.

2.4.3, 2.3.9

Nondestructive Testing of Large Forgings by Means of Ultrasonics. (In German.) W. FELIX. Schweiz. Arch. angew. Wiss. u. Tech, **17,** 107-113 (1951) Apr.

Metallographic tests prove the adequacy and accuracy of above method, which is thoroughly described. Includes diagrams, photographs, oscillograms, and and photomicrographs.—BLR.

2.4.3, 2.3.9

Non-Destructive Testing of Engineering Materials and Parts. R. C. MCMASTER AND S. A. WENK. *Materials and Methods*, **33,** No. 2, 81-96 (1951) Feb.; Materials and Methods Manual 67.

After reviewing the essential elements of non-destructive testing, and discussing briefly the selection of the method most appropriate to a particular problem, the authors describe the tests under the following headings: 1) penetrating radiation methods; 2) ultrasonic testing; 3) magnetic particle testing; 4) penetrant methods; 5) electro-magnetic induction tests; and 6) tribo-electric tests. Many commercial instruments are illustrated.—ZDA.

2.5, 6.2.3, 1.6

A.S.T.M. Specifications for Steel Flat Products. (Book) 198 pages. (p. 311-508). Mar. 1950. American Society for Testing Materials, 1916 Race St., Philadelphia 3. $2.25 (to ASTM members $1.75).

The various ASTM specifications pertaining to steel plate, sheet and strip materials, including those for steel flat products for structural purposes and for boilers and pressure vessels, prepared by Committee A-1 on Steel; also other specifications developed by Committees A-10, A-2 and A-5 on stainless flat products, wrought iron, and metallic coated sheets.—MR.

3. CHARACTERISTIC CORROSION PHENOMENA

3.2 Forms

3.2.2, 3.5.8, 6.3.6

Season Cracking Can Be Avoided by Cutting Down Internal Stresses. C. L. BULOW. Bridgeport Brass Co. *Copper Alloy Bulletin*, May 1951, 2pp.

When season cracking in service takes place, it is due to the combined action of ammonia, air and moisture on stressed material. The ammonia test is used to determine the presence of dangerous stresses in hard worked brasses, but it is not used as a standard method of control. Yellow brass (66 copper, 34 zinc) is less resistant to season cracking than the higher copper alloys such as red brass (85 copper, 15 zinc) and commercial (90 copper, 10 zinc). The rate of dezincification is not constant but rises and falls with the formation (polarization) and removal (de-polarization) of corrosion products which tend to stifle the reaction.—INCO.

3.2.2, 6.4.2, 3.7.4, 2.3.7

The Cracking of an Aluminum-Magnesium Alloy on Contact With Mercury. Part II. P. A. JACQUET AND A. R. WEILL. *Rev. aluminium* (France), **28,** No. 173, 4-10 (1951) Jan.

Results of investigation into the cracking of aluminum alloy containing 7 percent magnesium on contact with mercury show that there is no direct relation between the cracking and the micrographic structure, especially the presence or absence of the precipitated β constituent. However the cracking can be related to the heterogeneity of the form and shape of the grains. A relation seems to exist between the sensitiveness to cracking and the heterogeneity of the structure as revealed by X-rays. A supplementary deformation of the specimens without cracks by pressure increases the sensitiveness to intergranular attack and the structure becomes heterogeneous. None of the specimens showed any further cracks after a prolonged heat treatment at 160° C (320°F). In this connection, the X-ray diagrams showed a homogenization of the structure. The cracks in the aluminum spread through the grains in the exact way as in the stress corrosion of the same alloy. However, during stress corrosion, a certain degree of precipitation of β is necessary at the grain boundaries. The mercury test is of practical interest because it permits the detection of internal stresses due to the non-homogeneity of the plastic deformation which has great influence on service behavior.—ALL.

3.3 Biological Effects

3.3.2, 5.4.8, 2.2.5

Improvement of M559 Anti-Fouling Paint. M. KUSHNER. U. S. Naval Air Materiel Center, Rept. AML NAM AE 42439, 1950, 12 pp.

Tests on twelve anti-fouling systems for Naval aircraft hull bottoms are described. The proprietary vinyl finish shows best overall performance with good flexibility and adhesion, good resistance to fuel, oil and water immersion, and excellent fouling resistance in a summer-month test. Under similar conditions M-559 coatings were inferior in all respects except anti-fouling. Attempts to modify the greenish color of the proprietary finish by including blue and black pigments produced the desired sea-blue color, but seriously decreased fouling resistance.—RPI.

3.4 Chemical Effects

3.4.3, 5.3.2

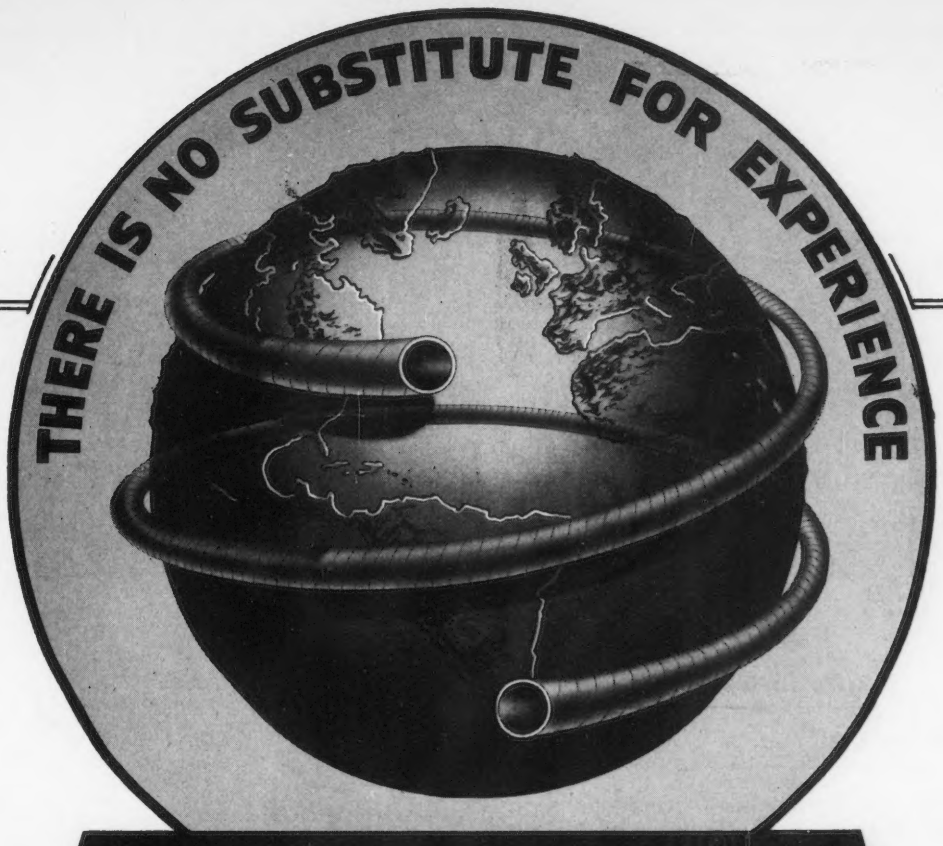
Zinc Plating Grows a Beard. Bell Laboratories. *Bell Labs. Record*, **29,** No. 6, 262-263 (1951) June.

Current leakage in electrical equipment was traced to the existence of very fine "whisker" formations (about 1u dia.) on certain zinc-plated steel components. Whiskers appear to be pure metal and they have been grown from zinc, cadmium and tin-plated surfaces. Copper coatings are to be used instead for this particular application, since they are thought not to behave in this way.—BNF.

3.4.6

The Theory of the Oxidation of Metals and Metallic Alloys. (In German.) K. HAUFFE. Parts I-III. *Werkstoffe u. Korrosion*, **2,** No. 4, 6, 7, 131-139, 221-231, 243-249 (1951) Apr., June, July.

A review of theories of the mechanism of metallic oxidation. The case of zinc is considered at some length. Zinc oxide is an electron-excess conductor, the ionic crystal lattice containing more zinc ions than the number required by the formula



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347

zinc oxide. The rate of oxidation depends mainly on the rate at which zinc ions reach the oxygen/zinc oxide boundary. Below atmospheric pressure, the rate of oxidation depends very little on the oxygen pressure.—ZDA.

Parts II & III. Formation of thin layers of tarnish on pure metals at lower temperatures, where oxide films cease to become thicker, is explained by electron-energy-level theory. Hole-formation theory explains sealing of metal alloys with ion-conducting layers, and scaling systems with excess and deficit electron-conducting layers. Effect of phase-boundary reactions during oxidation and growth of protective layers, theory of "internal oxidation" of metal alloys, and possibility of developing scale-resistant metal alloys are discussed. Includes diagrams, tables, and graphs. 41 references. —BLR.

3.4.6, 5.8.2

Role of Dissolved Oxygen During the Inhibition of the Corrosion of Iron by Sodium Phosphate Solutions. *Nature*, **167**, 157 (1951) Jan. 27.

Outlines results of investigation undertaken to determine the effect of dissolved oxygen on the corrosion rate of iron totally immersed in solutions of sodium phosphate at different pH values.—BLR.

3.5 Physical and Mechanical Effects

3.5.2, 8.9.5

The Distinguishing Characteristics of Water-formed Deposits. F. E. CLARKE. *J. Am. Soc. Naval Engrs.*, **63**, No. 1, 153-160 (1951) Feb.

Water-side deposits encountered in Naval service can be broken down into 5 fundamental types; scales, sludges, corrosion products, high temperature oxides and biological deposits. It is possible to detect and identify these deposits even when they are removed from their places of formation and mixed with deposits of other types. Water high in carbon dioxide content will develop metal carbonates on copper and nickel alloys. Iron oxide is the most prevalent corrosion product in Naval power plants but the oxides of copper nickel, lead and zinc also occur in appreciable quantities. Fundamental characteristics of deposits in accordance with definitions of the ASTM are discussed.—INCO.

3.5.3, 5.4.5

Erosion Protection. *Mech. Eng.*, **73**, No. 4, 327-328 (1951) Apr.

Problem in the use of plastic laminates for non-structural aircraft parts, such as the radar antenna housing, is rain erosion during high-speed flights. Studies, carried out by E. I. du Pont de Nemours & Co., show that of all the variables investigated, speed has the greatest effect on the rate of erosion of plastic laminates. Coatings made with neoprene appear to have the best resistance to rain erosion for they provide a durable, waterproof resilient coating for the laminate. These coatings are being considered to provide protection of the aluminum leading edges of high-speed aircraft.—INCO.

3.5.8

Influence of Internal Tension on Resistance to Corrosion Fatigue. (In French.) HANS BUHLER. *Metaux: Corrosion—Industries*, **26**, 142-144 (1951) Mar.

The above tensions created by hardening and their effect on improving resistance to bending and torsion of plain-carbon steel, were studied.

Earlier investigations had shown that internal stresses set up by quenching below the aluminum transformation point improved resistance to bending and to alternating torsion under normal conditions. Present paper extends the work to show the same treatment as conferring added resistance to alternating corrosion-fatigue. Work was done on carbon steel.

3.5.8, 2.3.7, 1.3, 6.2.4

A Critical Review of Notch Sensitivity in Stress-Rupture Tests. W. F. BROWN, JR. and G. SACHS. Natl. Advisory Comm. Aeronaut., TN 2433, Aug., 1951, 29 pp.

A review of the published English and German data on notch rupture investigations reveals the general influence of notching on the elevated-temperature long-time properties of chromium-molybdenum steels (0.3 carbon, 1.6 chromium, 1.3 molybdenum, 0.27 silicon, 0.1 vanadium) and chromium-nickel-molybdenum low-alloyed steels (0.7-0.8 chromium, 0.9-1.6 nickel, 1.0 maximum molybdenum). Highly ductile metals were not notch sensitive whereas a progressively increasing notch sensitivity developed if the unnotch rupture ductility fell below 5 percent. For heat-resisting low-alloy steels, the addition of nickel in amounts greater than 0.7 percent increases the notch rupture sensitivity greatly, and the elimination of nickel results in lower creep strength but reduced notch sensitivity. The quenched-and-tempered and the normalized-and-stress-relieved structures of these alloys were more notch sensitive than the annealed or spherodized structures. The notch sensitivity in chromium-nickel-molybdenum low-alloy steels appears to be associated with a time-and-temperature-development precipitation phenomenon, and is influenced by notch sharpness. Charts. 17 references. —INCO.

3.5.8, 3.5.9, 6.2.5

Preliminary Studies of the Effect of Oxidizing Sulfurous Atmospheres on the Rupture Strengths of Inconel "X" and Inconel. A. M. TALBOT and E.N. SKINNER. INCO. Paper, ASTM, 53rd Ann. Mtg., Atlantic City, June 26, 1950. ASTM Symposium on Corrosion of Materials at Elevated Temperatures. Spec. Tech. Publ. No. 108, 1951, 42-49.

Studies of stress and high-temperature corrosion simultaneously. Stress-rupture tests were made on Inconel and Inconel X in oxidizing sulfurous atmospheres with and without added water vapor. Inconel X was tested at 1350 and 1500 degrees F and tests on Inconel were made at 1800 degrees. Tests indicated that low moisture content oxidizing atmospheres containing as much as 1.0 sulfur dioxide are not particularly damaging to the short-time rupture strength of the Inconel-type alloys. In the case of Inconel tested at 1800 degrees F., the appreciably lower rupture strength and ductility suggest that the presence of water vapor decreases the resistance to attack by the sulfurous atmosphere. In sulfur free air at 1800 degrees F, the presence of water vapor results in improved rupture strength, possibly due to the strengthening effect of increased nitrogen adsorption. There is probably a limiting sulfur concentration within which alloys of this type may be relatively unaffected by prolonged high temperature exposure even in the presence of stress. Photomicrographs and graphs of results are given. —INCO.

3.5.8, 6.4.2

The Nature and Mechanism of Stress Corrosion in Wrought Aluminum Alloys.—I.-IV. H. VOSSKUHLER. *Werkstoffe u. Korrosion.* **1**, No. 4, 143-153; No. 5, 179-184; No. 8, 310-320; No. 9, 357-366 (1950).

A critical survey of stress-corrosion in aluminum alloys containing: (a) magnesium 3-9 and zinc >1%, (b) magnesium and zince in various ratios, with a total content of >10%, and (c) copper 3-4.5% and magnesium and manganese ~1% each. Stress-corrosion is one form of grain-boundary corrosion of which the other two forms are stress-free intercrystalline corrosion and layer corrosion and various combinations of these three forms are usually present together. For stress-corrosion to occur the alloy must: (a) be exposed to attack by a suitable corrosive medium, (b) have mech. stresses present within it, and (c) be in a condition which renders it susceptible to stress-corrosion. These factors are discussed in relation to: (1) type of stress-corrosion tests—(i) the shape of the specimen, (ii) the nature and magnitude of the stresses—whether causing a constant stress or a constant deformation, and (iii) the nature and condition of the corrosive medium—the composition of the atmosphere of solution, and whether exposure to it is continuous or intermittent; (2) the crystal structure of the material—(i) the solid solution concentration, and (ii) the grain-size and texture; (3) the method and degree of hot or cold working—rolling, forging, extrusion, etc.; and (4) the heat-treatment—(i) the time and temperature of solution-treatment, (ii) the nature of the quench, and (iii) the time and temperature of cold or warm ageing and whether or not the material has been given a small degree (> 10%) of cold work immediately after solution-treatment and quenching. There are numerous photomicrographs. 51 references.—MA.

3.5.8

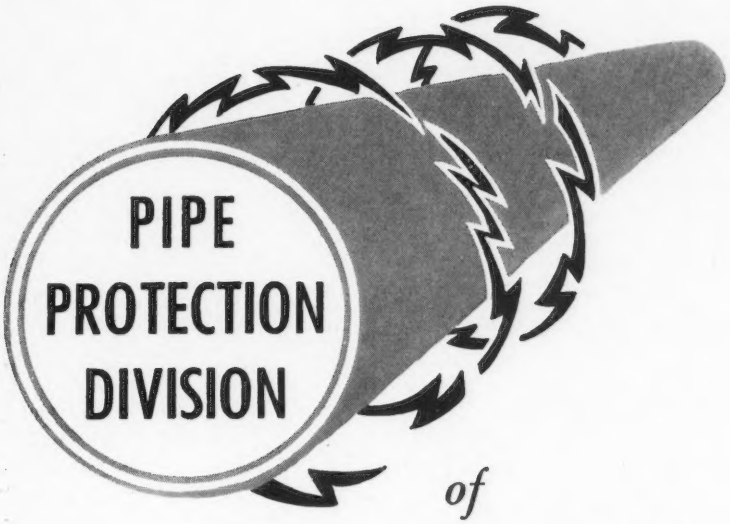
Deformation and Corrosion; Recent Russian Work on the Corrosion of Metals. *Chem. Age* (London), **65**, 153-155 (1951) Aug. 4. (Based on paper by E. M. ZARETSKII. *J. Applied Chem. USSR*, **24**, 477-484 (1951) May.)

Reviews some of the general ideas and factors involved in corrosion as affected by deformation, and described tests with various magnesium alloys, steel, copper, zinc, and aluminum, exposed to various forms of deformation and to different corrosion media. Includes graphs. 13 references.—BLR.

3.5.8, 3.5.2, 8.8.1

Mercury and Its Compounds—A Corrosion Hazard. M. H. BROWN, W. W. BINGER AND R. H. BROWN, Aluminum Research Laboratories, New Kensington, Pa. Paper Eighth Annual Conference, Natl. Assoc. Corrosion Engrs., Galveston, Texas, March 10-14, 1952. *Corrosion*, **8**, No. 5, 155-164 (1952) May.

Frequently cases of severe corrosion



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have been encountered with equipment fabricated of non-ferrous alloys that have long been considered standard for handling or processing a specific chemical. A review of the service history of such cases usually reveals the following pattern: 1) The equipment has functioned for considerable and even long periods of time without evidence of harmful corrosion; 2) Suddenly in a relatively short time, severe attack occurs. Routine examination failed to disclose the reason for the failures of equipment having such service records. Modified techniques for the examination of equipment having such histories of service reveal, in most cases, the presence of mercury in either the corrosion products, or on the metal surface in the vicinity of the attack or in the environment. This observation instigated a series of studies on the role of mercury and its compounds in promoting corrosion of metals, the concentration levels that might cause serious attack, and the manner by which such substances could be transported through chemical equipment and plants. It was found that the vapor pressure of metallic mercury even at low temperatures is sufficient to permit the mercury vapors to pass through the system and alloy with many commercial metals. This amalgamation of such metals can result in stress cracking or severe corrosion. It has been shown that metallic mercury reacts with many environments to a sufficient extent to produce compounds that are corrosive to commercial metals. It has been demonstrated that concentrations of mercury compounds as low as 0.5 ppm constitute a serious corrosion hazard for a variety of useful metals and alloys. The results of laboratory work and service experience have demonstrated that mercury contamination, either metallic or its compounds, constitutes a serious corrosion menace. It is believed that control of mercury contamination could easily be justified by the savings that would result from reduced replacement and maintenance of chemical process equipment.

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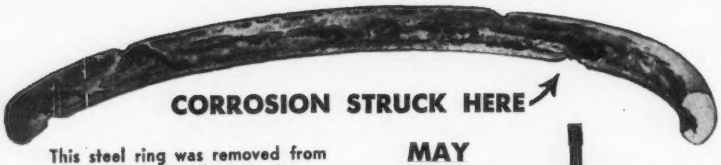

CORROSION STRUCK HERE

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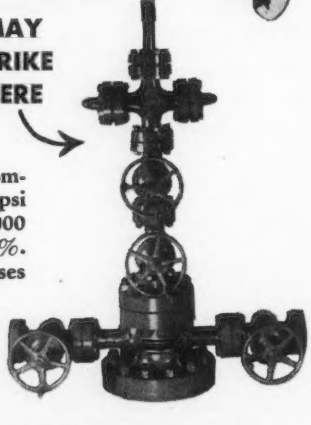

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3.5.9, 3.5.8, 7.1

Material and Performance. A. T. Bowden and W. Hryniszak. Iron and Steel Institute. "Symposium on High Temperature Steels and Alloys for Gas Turbines," 1951, pp. 11-17.

In terms of high temperatures and high stresses, corrosion, erosion, scaling, etc., consideration is given to the effect of using high-alloy steels upon the construction of the combustion chamber and heat-exchanger in the gas turbine partly from experience gained with the Parsons experimental gas turbine. The influence of the material on the construction of the compressor is also discussed. The choice of material is governed by the gas temperature, which is dependent on the required turbine-inlet temperature. The effect of the turbine-inlet temperature on the performance of the gas turbine was studied. The effect of artificial cooling is also briefly considered.—BLR.

3.6 Electrochemical Effects

3.6.8, 4.3.6, 6.4.2

Potential Buildup on Aluminum in Aqueous Common-Salt Solution. Part 2. (In German.) R. Ergang, C. Masing, and M. Mohling. *Z. Elektrochem.*, **55**, 160-165 (1951) Mar.

After reviewing earlier work on the electrochemical behavior of aluminum, a study of the true polarization of anode surfaces is described. Data are graphed and tabulated.—BLR.

3.7 Metallurgical Effects

3.7.3

Effect of Cold-Working on the Internal Friction of Iron and Steel, With or Without a Hydrogen Charge. (In French.) Paul Bastion and Pierre Azou. *Compt. rend.*, **232**, 1845-1948 (1951) May 16.

Study of 0.08 percent carbon steel showed that charging with hydrogen by immersion in a solution of hydrochloric acid and sodium sulfide has little effect on internal friction unless the steel is first plastically deformed.—BLR.

3.7.3, 3.5.8, 8.9.3

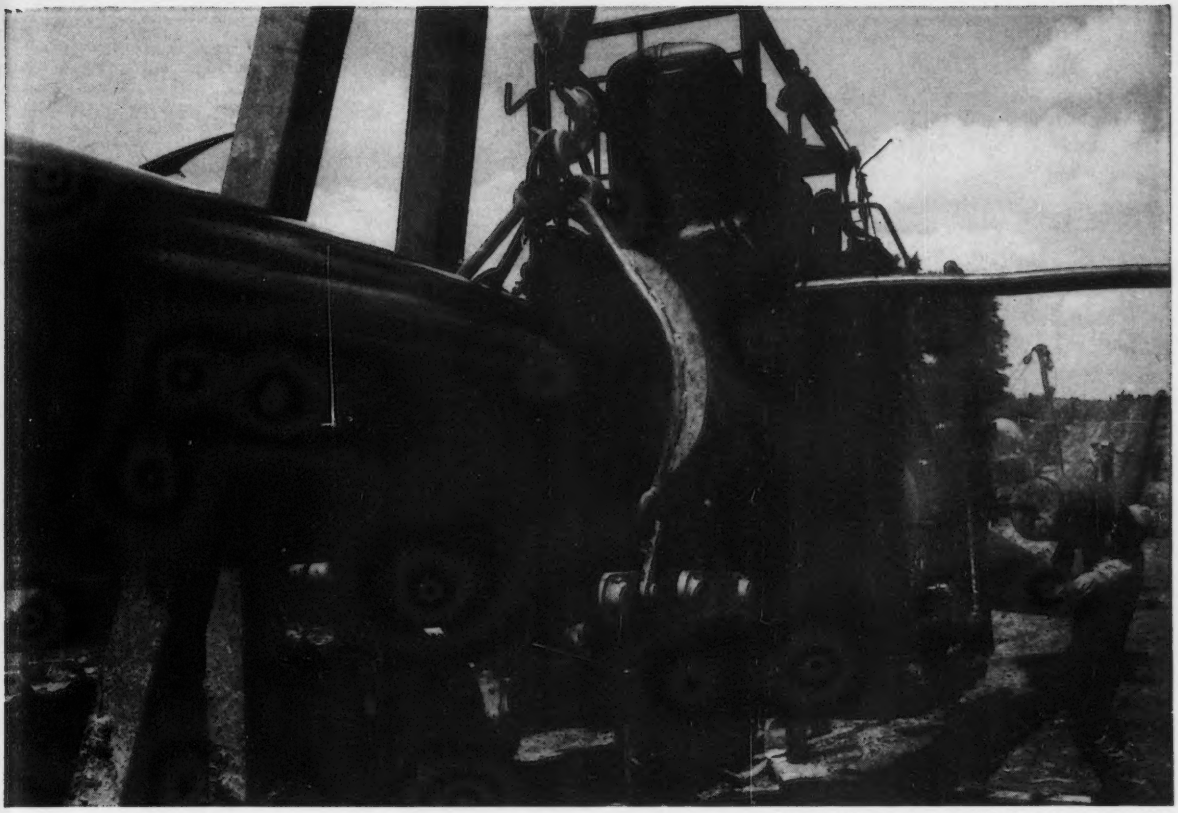
Residual Stresses in Butt-Welded Joints in Pipe Lines. (In Russian.) M. P. Anuchkin. *Avtogennoe Delo* (Acetylene Welding), **22**, 11-14 (1951) Jan.

The above were experimentally investigated in steel pipes 325 mm. in diameter having wall thicknesses of 10 mm. Diagrams show stress values and their distribution.—BLR.

3.7.3, 3.7.4

How Tool Life is Affected By Heat Resisting Alloys. *Automotive and Aviation Inds.* **104**, 52+(1951) Apr.

Gas turbine buckets are difficult to manufacture because in order to stand up under high forces and chemical attack at high temperatures, they must



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be fabricated from alloys which are extremely difficult to machine. Dynamometer cutting tests have brought out three major reasons for the difficulty in machining these alloys: 1) they exhibit extremely high shear strength during cutting; 2) they have the capacity for a high degree of work hardening during cutting—hence, act harder than normal during machining; 3) their microstrutures, due to work hardening and the presence of precipitated carbides, are highly abrasive when in contact with conventional sintered-carbide cutting tools. Tool-life tests clearly show how to machine the alloys to best advantage. Feeds and speeds, the grade of carbide used, and the microstructure all are very critical. With the bucket alloys, a cutting speed of 35 to 125 fpm and a feed of 0.009 to 0.014 in. per revolution will afford acceptable tool life if the metal is in the solution-treated condition, and a cast-iron grade tool is used. Turbine-bucket alloys are almost entirely unlike other engineering materials, and none of the present carbides seem entirely suited. Contrary to expectations, the cast-iron grade works out best, probably because of its higher hardness and abrasion resistance. This article is extracted from one chapter of a 162-page book recently published by Curtis-Wright Corp. for the Machinability Research Program sponsored by the U. S. Air Force.—TDD.

3.7.4

Intercrystalline Corrosion of Alloys. (In Russian.) G. V. Akimov. *Bull. acad. sci. USSR* (Izvestiya Akad. Nauk SSSR). Section of Chemical Sciences, 1951, 13-24 Jan.-Feb.

Analyzes different theories of intercrystalline corrosion and strongly emphasizes the theory of polyelectrode systems. A new "microelectrochemical" method of investigation is proposed and described in detail. This method, based on the theory of polyelectrode systems, makes it possible to plot a true polarization (corrosion) diagram, thus presenting an objective electrochemical characterization of the process of interaction of crystallites and their boundaries. Briefly reviews protective methods against intercrystalline corrosion. Data are tabulated and charted. 25 references.

3.7.4, 3.4.6

On the Theory of Scaling (Oxidation) Processes in Metal Alloys. Karl Haufe. *Metall*, **4**, Nos. 21-22, 462-463 (1950).

A brief review of the mechanism—based on the Wagner-Schottky theory of lattice defects, and the Wagner theory of scaling (oxidation)—whereby: 1) additions of lead or cadmium to silver reduce the rate of formation of the silver bromide films—which are ionic conductors—formed by bromination at 300° C, and 2) additions of aluminum and lithium reduce and increase, respectively, the rate of formation of zinc oxide films, which are electronic conductors. 7 references.—MA.

3.7.4, 6.4.4

Theory of Metals and Alloys. W. Hume-Rothery. *Metal Treatment and Drop Forging*, **17**, 15-22 (1950) Spring.

How a theoretical consideration of atomic systems may help to produce alloys with desired properties. Electron theory, its relation to formation of solid solutions, and factors involved in the combination of metal atoms, using magnesium alloys as examples.—MR.

3.7.4, 3.5.2

Surface Problems of the Chemical Behaviour (Corrosion) of Metallic Materials. W. Buertler. *Metalloberflache* (Germany (A) **3**, No. 7, 133-141 (1949).

After differentiating between chemical attack in which material is removed and that in which material is added (i.e. where film formation occurs), the author discusses the relationship between such attack and the crystal structure of the material. Where corrosion results in removal of material then, in the case of single crystals, the resistance to attack decreases in the order: face-centered-cubic→hexagonal→body-centered cubic structure. Differences in the rate of reaction also occur within the individual types of crystal, as a result of the differing orientations of the constituent atoms at the various corners, edges, and plane surfaces. Thus, in face-centered cubes the octahedral planes are the most resistant and dodecahedral the least resistant to attack, while in body-centered cubes octahedral planes show the least resistance and the cube and dodecahedral planes the most resistance; hexagonal prisms are more resistant on the basal plane than on the prism faces, and if the latter are to have the greatest possible resistance they should be perpendicular to the basal plane. Subject to their being homogeneous, solid solutions behave similarly to single crystals; heterogeneity increases corrosion, especially at corners and edges. When the behavior of polycrystalline aggregates is consid-

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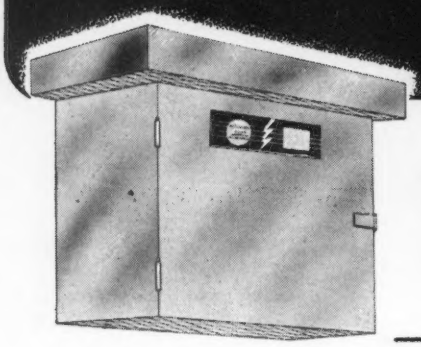

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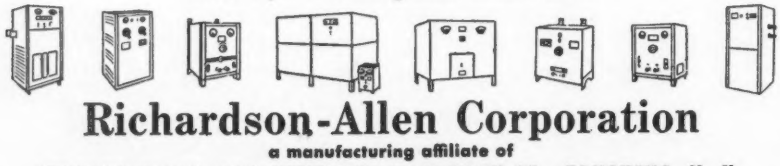

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ered the relative orientations of the individual crystals must be taken into account; not only do grain boundaries play an important part in determining the rate of attack, but local cell effects appear and complicate the reactions. Where chemical attack results in the formation of corrosion products on the surface of the material, the progress of the reaction is determined by the nature and properties of such films, i.e. whether or not they are adherent, continuous, or permeable. The corrosion and corrosion-resistance of iron, cobalt, nickel, aluminum, and magnesium and their alloys, and stainless steels are discussed in relation to the above-mentioned factors.—MA.

3.8 Miscellaneous Principles

3.8.2, 1.3

The Kinetics of Hydrogen Evolution as a Function of Electrode Material. (In German.) J. O'M. Bockris. *Z. Elektrochem.*, **55**, 105-111 (1951) Mar.

Review of literature on above shows that there are three groups of metals, each of them having a different reaction mechanism of hydrogen evolution. Results of different authors are critically evaluated and data are charted and tabulated. 25 references.—BLR.

3.8.2, 3.4.8

Concentration Polarization of a Silver Electrode. K. Nagel and Th. Renner. *Z. Elektrochem.*, **54**, No. 7, 547-556 (1950).

Simple polarization of an electrode, unaccompanied by complications, may be one of three types, resistance-, activation-, or concentration-polarization. The polarization of a silver electrode, studied for small concentration of silver ions in various electrolytes, e.g. sodium perchlorate, perchloric acid, potassium nitrate, is shown, in accordance with anticipation, to be attributable to concentration effects. Departure from the purely concentration type of polarization is attributable to the residual co-operation of other potential-determining processes and other types of polarization. 26 references.—MA.

3.8.2, 6.2.2

The Electrochemical Behavior of Iron. (In German.) K. F. Bonhoeffer. *Z. Elektrochem.*, **55**, 151-154 (1951) Mar.

Charts and discusses the voltage curves of 11 different types of iron in acid electrolytes. Resistance to polarization was found to be highly dependent on the iron and is definitely related to corrosion rate. The behavior of iron is qualitatively explained by the kinetic theory of electrochemical equilibrium.—MR.

3.8.2, 6.2.2

The Electrolytic and Chemical Passivation and Activation of Iron. (In German.) K. F. Bonhoeffer and U. F. Franck. *Z. Elektrochem.*, **55**, 180-184 (1951) Apr.

Using the equivalent-current density concept, anodic passivation of iron in sulfuric acid and chemical passivation by nitric acid are studied. This concept is shown to be suitable for dealing with the neutralization of passivity by cathodic treatment or by hydrochloric acid.—MR.

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3.8.3, 5.8.3

The Electrostatic Inhibition of Ion Adsorption at Metal Surfaces. OTTO ERBACHER. *Z. Elektrochem.*, **54**, No. 5, 369-374 (1950).

From the consideration of many examples of ion adsorption at metal surfaces in acids and other liquids, e.g. the adsorption of Bi^{3+} on silver, Pb^{2+} on silver or Mercury, Tl^{+} on mercury, the author concludes that adsorption of metal ions at metal surfaces is to be regarded not as the result of the summation of a number of Langmuir isotherms attributable to a number of activation centers, but rather as arising from the mutual electrostatic inhibition of ion adsorption. —MA.

3.8.4

Reactions of Ferrous and Ferric Ions With Hydrogen Peroxide. Part I. The Ferrous Ion Reaction. Part II. The Ferric Ion Reaction. W. G. BARB, J. H. BAXENDALE, P. GEORGE, AND K. R. HARGRAVE. *Trans. Faraday Soc.*, **47**, 462-500, 591-616 (1951) May, June.

Part I. Investigation of the $Fe^{++} + H_2O_2$ system revealed several new features. A consistent reaction mechanism involving the radicals HO and HO_2 is proposed. Detailed analysis of kinetic and oxygen-evolution data for the system under certain experimental conditions led to values for ratios of velocity constants for reactions of ferric, ferrous, and cupric ions with the HO_2 radical. 26 references.

Part II. The kinetics of the ferric-ion catalyzed decompositon of H_2O_2 are deduced on the basis of the reaction steps found necessary in the ferrous-ion system. These lead to three different kinetic expressions depending on the ratio of concentrations of H_2O_2 and Fe^{+++}. Previous work is discussed in terms of these expressions. Describes method developed for measuring concentration of Fe^{++} in equilibrium with Fe^{+++} and H_2O_2. 23 references.—BLR.

3.8.4, 3.5.9, 3.4.6

Epitaxial Growth of Iron Protoxide Crystals by Careful Oxidation of Iron at High Temperatures. (In French.) JACQUES BENARD AND JEAN BARDOLLE. *Compt. Rend.*, **232**, 2217-2218 (1951) June 11.

Describes above for low pressures and shows that it favors a relationship of orientation between the oxide and the metal beneath, permits formation of epitaxial layers of notable thickness and with characteristic geometric form, and makes evident some inequalites in rate of growth.—BLR.

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4. CORROSIVE ENVIRONMENTS

4.2 Atmospheric

4.2.5, 2.2.2

Impact Deposition of Atmospheric Sea Salts on a Test Plate. ALFRED H. WOODCOCK. *Proc. Am. Soc. Testing Materials*, **50**, 1151-1166 (1950).

Rusting of structural steels at Block Island, R. I., and at Kure Beach, N. C., has been attributed in major part to the presence of chlorides on the test plates. Indicates the weight and the number of sea-salt nuclei which were deposited on surfaces by impact during the passage of marine winds in the Block Island region. Suggests that impact deposition may largely acount for the presence of chlorides on these plates.—MR.

4.3 Chemicals, Inorganic

4.3.5, 2.3.6

Periodic Phenomena in the Attack of Metals by Vapour: Application to the Determination of Rates of Corrosion (of Silver and Copper). RENE DUBRISAY AND FRANCOIS ARLET. *Rev. Met.*, **48**, No. 4, 267-270 (1951).

The authors investigated the phenomena wherein, if a sheet of silver or copper pierced with a hole is placed on a tube containing a piece of iodine, a series of concentric colored rings is formed with the hole as center. They measured the diameter of the rings under monochromatic (Na) light and applied the formula: $e = Kp\lambda$, where e is the thickness of the layer, λ the wave-length (of Na light), p the order of the ring from the center, and K a coefficient depending solely on the refractive index of the iodide. They tabulated and plotted the results at room temperature, and at 24 degrees, 46 degrees and 60 degrees C. At all these temperatures the curves are similar and indicate a complex mechanism, for which various theories have already been put forward. It appears certain that two factors are the rate of attack of the metal by the vapor and the time that the vapor is at the hole. Curves of the thickness of the iodide against the time show that the rate of

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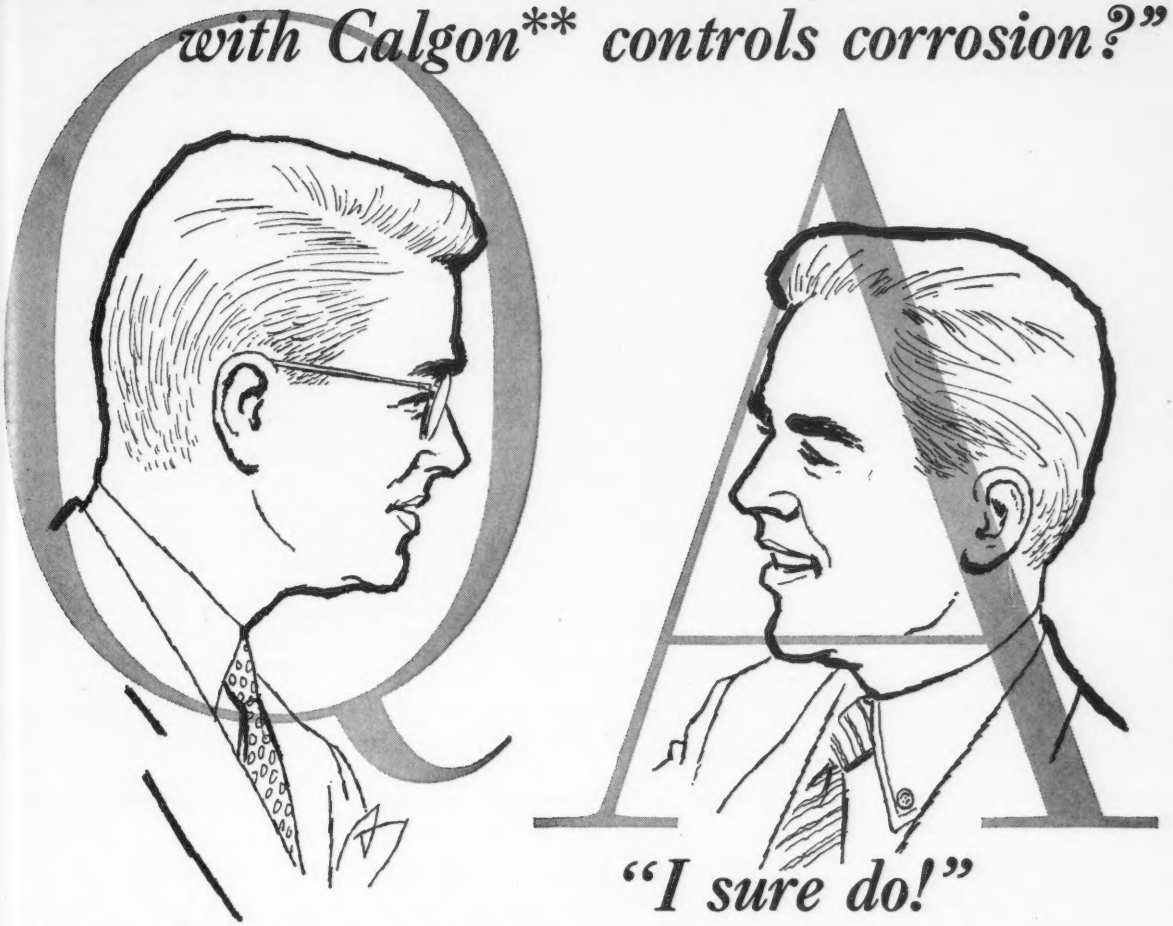

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corrosion is very high at first and diminishes rapidly with the time and that it increases with the temperature up to a certain point, after which it diminishes—an unexpected result. Above 100 degrees C the appearance changes completely; some rings are seen at once and these increase in size, but not in number. With bromine no rings are obtained at room temperature, but some may appear at 0 degrees C. With electrolytically polished silver or copper the results are the same as at temperatures above 100 degrees C and no rings appear. The rate of formation of rings increases with the decrease in size of the tube.—MA.

4.6 Water and Steam

4.6.4, 3.4.7

Improvised Sulphur Burner Saved Half Billion Gallons per Year of Tower Blowdown. V. F. ESTCOURT. Pacific Gas and Electric Company. *Oil and Gas J.*, **50**, No. 6, 105 (1951) June.

This cooling tower installation which employs complex phosphate treatment uses a sulfur burner to provide the sulfate radical for the formation of sulfuric acid with tower water to maintain the pH between 7.9 and 8.1. By maintaining careful pH control, it is possible to operate with tower water concentration between four and six times that of the makeup water, thereby realizing large savings in tower blowdown. The water is also treated by chlorination to prevent algae growth that reduces tower efficiency and heat transfer rates in condenser tubes.—NALCO.

4.6.4, 6.6.11

Delignification of Redwood Cooling Tower. MAXEY BROOKE. Phillips Oil Co. *Petro. Eng.*, **23**, No. 4, C-38 (1951) April.

Numerous tests were conducted, both on operating cooling towers and with laboratory block tests. The author concludes that delignification of redwood cooling tower lumber is a function of the pH of the cooling water and independent of the salt concentration of the water.—NALCO.

5. PREVENTIVE MEASURES

5.2 Cathodic Protection

5.2.3, 8.4.2

How Cathodic Protection Was Applied to the Underside of a Water-Seal Holder. E. H. GREBSTAD AND T. H. GILBERT. Paper presented at the Pacific Coast Gas Assoc., Technical Services Conferences in Los Angeles, March 7-8, 1951. *Gas*, **27**, No. 4, 41-43 (1951) Apr.

By measuring resistance and using a system of distributed vertical graphite anodes, cathodic protection against corrosion was accomplished on the underside of a waterseal holder. Diagrams showing potential measurement, installation and location of anodes are included with a discussion of soil properties test procedures and results.

5.3 Metallic Coatings

5.3.2, 4.3.2

Antimony Plate. A. BREGMAN. *Metal Progress*, **59**, No. 2, 245-247 (1951) Feb.

Author points out that it is not generally appreciated that pure antimony resists attack by hydrochloric acid and hydrofluoric acid, is relatively tarnish resistant and easily buffed to a highly reflective surface. Successful plating techniques, he suggests, make it a substitute for the more critical metals, nickel and chromium.—BNF.

5.3.2, 5.3.4, 5.4.2, 5.4.5

Metal Finishing of Household Equipment at Servel's Plant. ADOLPH BREGMAN. *Metal Progress*, **59**, 646-649 (1951) May.

Metal finishes employed by Servel fall into two classes, the entirely functional and those that are both functional and decorative. In the first group there are the copper, zinc, and tin electroplates, galvanizing, zinc metallizing and aluminizing. The second group embraces the nonmetallic coatings such as baked enamels, black and aluminized black Japans, porcelain enamel, and "plastic coatings." In addition, a number of surface treatments are employed either as a preparatory step for subsequent surface coating or as a corrosion-preventive process. Briefly outlines processes and equipment.—BLR.

5.3.4

Metal Spraying in France. J. CAUCHETIER. *Electroplating*, **4**, No. 5, 163-164 (1951) May.

The author says that the perfect protection afforded by zinc spraying a metal lock gate in 1922 has encouraged the Administration de la Ville de Paris to have all its lock gates zinc sprayed. The French navy is also using the process extensively for hulls and other parts in steel or aluminum. On the railways it is being used for protecting carriage roofs. —ZDA.

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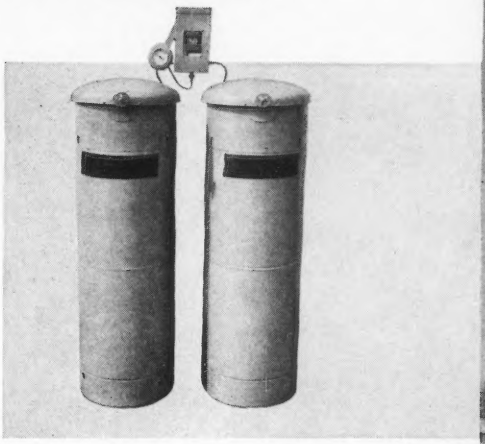

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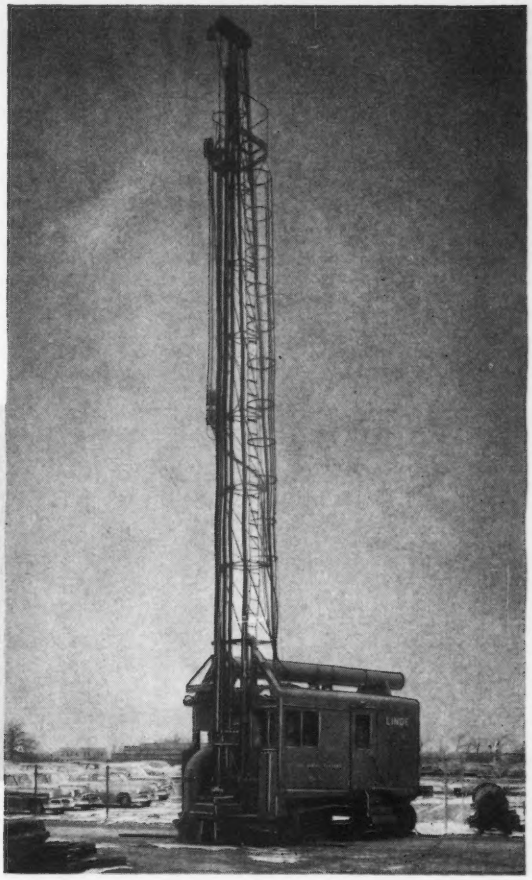

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5.3.4

Prevention of Corrosion by Metal-Spraying. (In German.) H. BIEL. *Werkstoffe und Korrosion,* **2,** 182-185 (1951) May.

A coefficient derived from the heat content of each metal is used to determine rate of supply in wire-spraying apparatus and particle-size of the metal in powder-spraying apparatus. Efficiency of powder-spraying apparatus is said to be higher than that of wire-spraying apparatus. The first are used for non-metallic materials, hard metals and partly for zinc. Corrosion tests are discussed which showed a decrease of resistance in the following order: wire-sprayed, powder-sprayed, coatings prepared electrolytically or by dipping into molten zinc.—INCO.

5.3.4, 1.7.1

Report of (ASTM) Committee B-8 on Electrodeposited Metallic Coatings. Am. Soc. Testing Materials Preprint 13, 1951, 27 pp.

Gives three proposed tentative recommended practices: 1) Preparation of zinc-base die castings for plating (pp. 519), covering alloys, polishing, buffing, degreasing, electrocleaning, acid dipping and copper strike. 2) Preparation of and plating on aluminum alloys (pp. 10-19) dealing with cleaning; zincate immersion process; copper strike; brass, cadmium, copper, chromium, gold, nickel, silver and zinc plating; racking and rinsing. 3) Preparation of and plating on stainless steel (pp. 20-24) specifying cleaning, racking, activation, rinsing, plating, stripping and testing procedures. Appended to this report is "Report of Subcommittee II on Performance Tests" (ASTM Preprint 13S, 1951, 10 pp.), giving results of atmospheric exposure tests on copper/nickel/chromium deposits on high-carbon steel.—BNF.

5.3.2, 6.2.3, 2.2.5

Corrosion Resistance of Metallized Steel. *Chem. Eng. News,* **29,** No. 31, 3094 (1951) July 30.

The American Welding Society's committee on metallizing has organized a test program to determine the corrosion resistance of steel having metallized coatings of zinc and aluminum under exposure to different atmospheres. Duplicated steel specimens will be sprayed with aluminum and zinc coatings varying in thickness from 0.003 inch to 0.015 inch with and without vinyl cover coats. Preparation of more than 4000 test specimens is underway. They will be assembled for exposure at several standard corrosion tests sites. Exposure will be for periods of one, three, six and twelve years. The program is intended to provide authoritative data on the thickness of zinc or aluminum to use for different exposures for various lengths of time. Types of exposure include sea water, marine atmosphere and different industrial atmospheres. Specimens will be examined at regular intervals and periodic reports issued.—ALL.

5.3.4

Maintenance by Metallizing. GILBERT C. CLOSE. *Finish,* **8,** 23-26, 78-80 (1951) Aug.

Mechanics of the metallizing process. From the metallurgical standpoint, the spray metal does not fuse with the surface on which it is applied, but secures a bond by keying and hardening around minute surface irregularities. Various applications.—MR.

5.3.4, 5.2.2, 5.8.2

Some Fundamentals of Corrosion and Protection. M. A. COMLEY. *Ind. Finishing.* (U.K.). **3,** No. 37, 976-980 (1951) July; *Electroplating & Metal Finishing,* **4,** 229 (1951) July.

In this paper, presented to the Birmingham Section of the Metal Finishing Association, the author reviews the cost of corrosion, its mechanism and ways of controlling it. Methods of protection include cathodic protection using anodes of a more corrodible metal such as zinc or magnesium, the use of inhibitors, phosphate or zinc hydroxide coatings, electrochemically-deposited coatings and metallic coatings deposited by electrodeposition or as a paint. There is no reference to other methods of applying protective metallic coatings.

5.3.4, 5.8.3

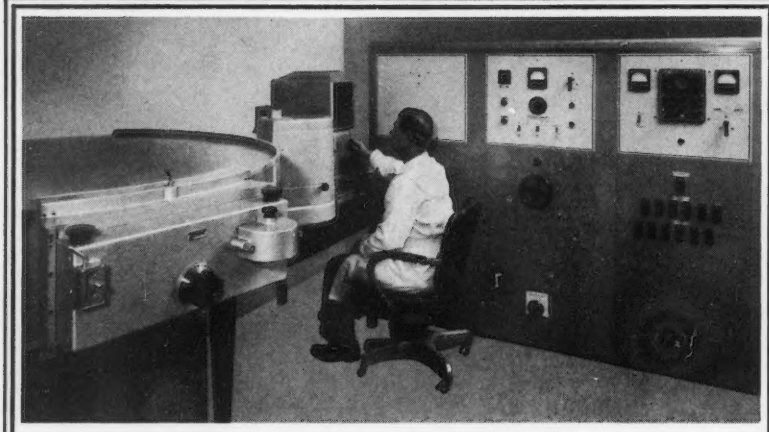
The Cause of the Inhibition (of Zinc Attack) by Aluminum in Galvanizing Baths. H. BABLIK, F. GOTZL AND R. KUKACZKA. (In German.) *Werkstoffe u. Korrosion,* **2,** No. 5, 163-165 (1951) May.

Authors attempt an explanation of the effect of aluminum in the galvanizing bath, but the paper adds little to knowledge of the subject.—BNF.

5.3.4, 6.3.19

Protective Bright Dip for Zinc. *Electroplating,* **4,** No. 4, 128 (1951) April.

A summary of British Patent 636,954 (Poor and Co. Inc.) in which a method is described for brightening a zinc surface and at the same time conferring a degree of passivation on it. In an exam-



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ple quoted, a dull zinc electrodeposit was dipped in a chromic acid-ammonium persulphate solution containing liquorice as a wetting agent, rinsed and dipped in a dilute solution of sodium hydroxide and sodium hydrosulphite. It is claimed that a lustrous coating was formed, which held its color when subjected to a 100-hour salt spray.—ZDA.

5.4 Non-Metallic Coatings and Paints

5.4.1, 5.8.4

Survey of the Application and Performance of Temporary Rust Preventives. G. T. DUNKLEY. *Sheet Metal Inds.*, 27, 599-606 (1950); *J. Iron Steel Inst.*, 168, Pt. 1, 111-112 (1951).

This is a descriptive survey of the various types of preventive, their advantages and disadvantages, and precautions to be taken in use. The author considers these materials under three headings as follows: 1) Hard film compounds, which may be divided into those formed by the evaporation of a solvent, and those which are applied hot and form hard strippable coatings. The former are based on bitumen or resins plus lanolin, and the latter on ethyl cellulose plus oils, resins, and plasticisers. 2) Soft film compounds, such as white lead/tallow mixtures, petroleum jelly plus beeswax or lanolin, lubricating oils plus lime soap and where rubber is present castor-oil-base greases. 3) Oil film compounds which are ordinary lubricating oils to which have been added rust inhibitors. Vapor-phase inhibitors are becoming increasingly popular for protecting delicate mechanisms such as clocks.—RPI.

5.4.2, 3.4.6

Ceramic Coatings Prevent Exhaust-Gas Corrosion. *Better Enameling*, 22, 6-7, 30 (1951) July.

Five heat-resisting alloys were investigated for use in coated aircraft exhaust systems; Inconel (a high nickel alloy), Types 347 and 19-9DL stainless steels. Vitallium, and S-816. Specimens of each alloy with 5 different coating conditions were studied; an uncoated specimen, a preoxidized specimen and 3 ceramic-coated specimens. Illustrations. Data tabulated.—BLR.

5.4.2, 3.5.9

Heat Resistant Ceramic Coating Permit Substitutes for Critical Materials. D. G. BENNETT. Univ. Ill. *Materials & Methods*, 33, No. 3, 65-67 (1951) Mar.

Application of a ceramic coating to Type 347 stainless steel increased resistance to oxidation at 2000 degrees F greatly. Curves demonstrate the temperature difference between the outer surface of an ordinary Inconel flame tube and the surface of others which were internally protected with ceramic coatings.—INCO.

5.4.2, 5.4.8

An Investigation of the Use of Phosphates for Coating Beryllium Carbide Underbodies Containing Admixed Graphite. T. H. ELMER. Nuclear Energy for Propulsion of Aircraft, Oak Ridge, Tenn. April 1951. 10 pp. (NEPA-1805).

The feasibility of using phosphate glazes as coatings for underbodies composed of beryllium carbide and graphite was investigated. It was found that the phosphates are readily reduced at temperatures below 1400 degrees C by carbon and beryllium carbide. The glassy phase was destroyed in the course of reduction, leaving a loose oxide layer on the surface of the underbody. Phosphorus was lost from the phosphate compounds during the reduction. Phosphates were found to be reduced more rapidly by hydrogen than by beryllium carbide, lanthanum phosphate nad cerium phosphate were found to be stable at temperatures up to 1700 degrees C, whereas all other phosphates investigated were found to decompose partially or completely at much lower temperatures.—NSA.

5.4.2, 5.4.8

Ceramics for the Hot Spots; The Role of Heat Resistant Coatings in the Aircraft Industry. *Better Enameling*, 22, 8-11 (1951) May.

Practice at Ryan Aeronautical Co. In order to withstand temperatures above 1900 degrees C, ceramic coatings are applied to heat resistant alloy steels.—MR.

5.4.2, 6.2.3, 3.5.9

Refractory Facing on Mild Steel. *Engineering*, 171, 763 (1951) June 22.(From Report 50/4/73, Industrial Gas Development Committees, Gas Council, London.)

Outlines process for protection of mild steel against the effects of high temperature, in which the steel is given a refractory coating. The process consists in carrying, in a borosilicate matrix, a

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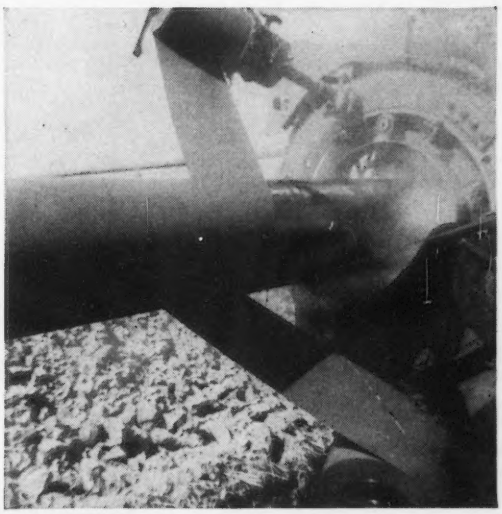

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suspension of insoluble refractory material and bonding it to the metal surface by fusion at about 800 degrees C. Properties of the coating depend on proportion of refractory matrix, particle size, number of layers present and porosity of the upper face.—BLR.

5.4.2, 6.4.4

HAE Coating Development Indicates Wider Magnesium Use. *Chem. Eng. News,* **29,** No. 24, 2387 (1951) June 11.

The Army Ordnance Corps has announced the development of a new finish for magnesium and magnesium alloys. Known as HAE, the process produces electrolytically a hard, adherent, refractory ceramic coating in a manner similar to anodizing. The coating was developed by H. A. Evengelides, for whom the process was named. Because of its high corrosion resistance, HAE will probably create wider applications for magnesium in fields where corrosion has been a limiting factor. Salt spray tests conducted on HAE treated alloy panels showed no corrosion detectable with the unaided eye up to about 90 hours.—INCO.

5.4.2, 6.6.6, 7.1

New Insulating Materials and Coatings Extend Electric Motor Life. Richard L. Custis. *Materials and Methods,* **33,** 74-75 (1951) Mar.

Describes properties and use of Fiberglas tubing and laminates and new insulating varnish which effectively withstand corrosive atmospheres, high temperatures and effects of dirt and oil.—BLR.

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5.4.2, 7.1, 8.9.1

Porcelain Enamel Solves Aircraft Engine Problem. *Ceramic Industry,* **56,** 72-73+ (1951) June.

Use of ceramic coatings at Ryan Aeronautical Co. to give improved resistance to heat and corrosive effects of exhaust gases in the exhaust systems of new aircraft piston engines.—MR.

5.4.2, 7.1, 8.9.1

Ceramics Exhaust Protection. *Aviation Week,* **54,** No. 21, 30 (1951) May 21.

The potential ceramics is being exploited to lick exhaust system problems in high-power piston engines. Ceramics for this application is not entirely new. In World War II, Ryan Aeronautical Co. turned out more than 500 exhaust systems with thick enamel coatings for the Douglas A-20 attack bomber, when the low-carbon SAE 1020 steel was used instead of the critically short stainless. But Ryan is still pushing its development studies because the necessity for improved heat-resistance and for checking corrosion in exhaust systems has greatly increased. Today's piston plants, with their boosted power and higher exhaust temperatures, have created more severe operating conditions for exhaust system components. Now Ryan, Boeing, and Pan-American Airways engineers are teamed in tests on thin coatings of 0.001-0.003-in. ceramics on Ryan-built exhaust parts in a PAA Stratocruiser operating under regular service conditions on trans-Pacific runs. Report is that future systems for Boeing B-50's and C-97 Stratofreighters will incorporate ceramics for protection.—TDD.

5.4.2, 7.1, 8.9.1

Tests of Ceramic Coatings for Engine Exhaust Systems. *Automotive and Aviation Inds.,* **105,** No. 3, 36-37 (1951) Aug. 1.

Lead bromide vapors have proven corrosive to aircraft exhaust systems. In a study of this, the Nat. Bur. Stds. has found that uncoated alloys corrode fairly rapidly when exposed to lead bromide vapors at high temperatures while certain ceramic coatings effectively prevent corrosion under the same conditions. Tests show that uncoated alloys S-816, Vitallium, and Inconel are more resistant to corrosion than 19-9 DL and Type 347 stainless steels. Preoxidation retarded corrosion for only 1-2 hours. Data are tabulated.

5.4.2, 7.7, 4.2.5, 4.2.4

Coastal Finish Extends Life of Distribution Transformers. J. G. Ford and A. J. Kuti. *Westinghouse Eng.,* **11,** No. 2, 42-45 (1951) March.

"Coastal finish" is a 3-coat non-metallic finish for steel, incorporating mica flakes, for protection against marine and industrial atmospheres. Article includes results of tests of "Coastal" and ordinary finishes (galvanized, Cd-plated, etc.).—BNF.

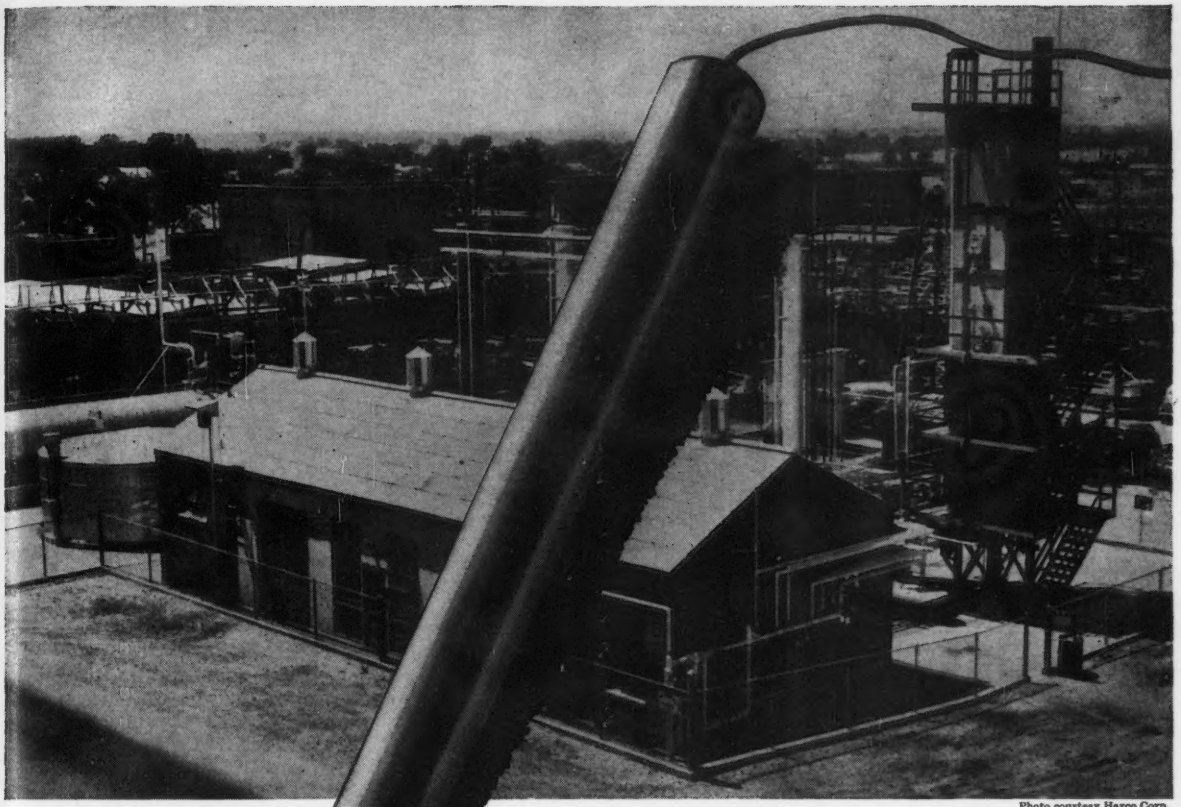
5.4.5

Bituminous Protectives. Association of Manufacturers of Bituminous Protective Products. Booklet, 1951, 26 pp.

The raw materials, composition and application of bituminous paints, coating compositions, etc., are described.—RPI.

5.4.5

Lead Pigments. Red Lead. M. J.



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BEDDELEEM. *Trav. peinture*, **6**, No. 2, 32-35 (1951).

The composition and use in paints of red lead are discussed. The best vehicle is held to be linseed oil, with perhaps a small addition of stand oil; other oils and oleo-resinous media, have certain practical disadvantages. Colloidal red lead, lead-coated pigments, phosphating of iron prior to painting, the preparation of stable red lead paints and other topics are dealt with.—RPI.

5.4.5

New Rust-Binding Paint. O. BERGOLD. *Farbe u. Lack*, **57**, No. 1, 24 (1951).

The medium of a new anti-corrosive paint consists of an acid-hardening resin which reacts with the rust components—oxide, water and traces of acid—and in effect combines them into the resin molecule.—RPI.

5.4.5, 1.7.1

Fight Against Corrosion in Belgium—Work Done by Commission No. IV of the ABEM in 1948-50. *Chim. Peintures*, **14**, No. 1, 12-14 (1951).

A large outdoor exposure program is in progress and a new accelerated weathering test has been investigated. A general study of the relation of the vehicle and pigmentation to paint performance is being undertaken and tests in cooperation with the British Protective Coatings Sub-Committee have been instituted. Investigations continue into methods of preparation of various metals before painting.—RPI.

5.4.5, 6.3.1, 2.3.7

Investigation of the Nature of the Adhesion of Lacquers to Non-Ferrous Metals. L. R. BRANTLEY, A. E. WOODWARD AND G. CARPENTER. Reviewed in *American Paint Journal* (U.S.A.) **35**, No. 44, 76 (1951) July 23.

This paper is the result of an investigation with an ivory knife adherometer of several of the factors responsible for the adhesion of simple organic coatings to aluminum. The results of experiments showing the effect of the composition of the lacquer on its adhesion to 24ST aluminum are described. In the case of both nitrocellulose and ethylcellulose lacquers plasticized with dibutyl phthalate, an optimum plasticizer percentage was found. Experiments were designed to show the effect of the percentage of polar groups in the film former on its adhesion. It was found that for nitrocellulose lacquers differing only in the percent nitration of the cellulose, the adhesion to aluminum increased with the percent of nitration. No appreciable effect on the adhesion to aluminum was obtained for ethylcellulose. The effect of the degree of polymerization of the film former on its adhesion to aluminum was investigated. Nitrocellulose lacquers, differing from one another only in the degree of polymerization of the polymer showed a maximum in adhesion in the intermediate range of polymerization. An investigation of the loss in adhesion of ethylcellulose lacquer coatings on a series of metals with different coefficients of expansion during hot and cold cycling showed that the resulting loss in adhesion was roughly proportional to the difference in the expansion coefficient of the lacquer coating and the metal used.—ALL.

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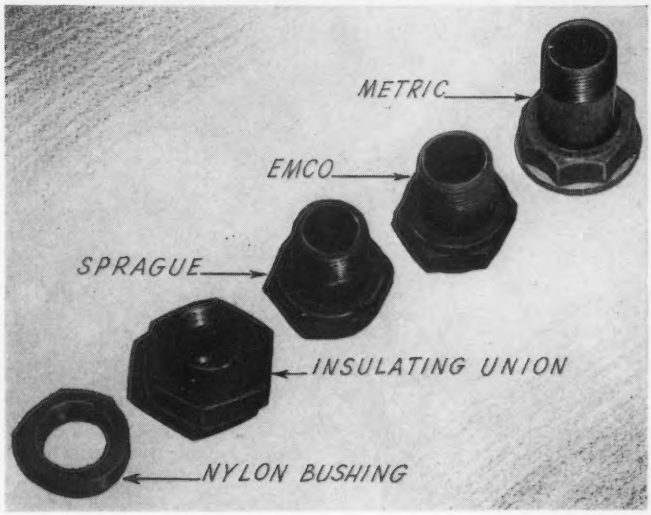

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5.4.5, 6.3.1, 6.4.1

The Painting of Non-Ferrous Metals. A New BSI Code of Practice. *Product Finishing* (England), **3,** No. 12, 80-82+ (1950).

A summary of the recommendations contained in a Draft Code of Practice Specification relating to the painting of non-ferrous metals in the building industry prepared by the British Standards Institution.—ALL.

5.4.5, 8.9.5

Underwater Paints for Rust Protection of Ships' Bottoms. W. SCHLICK. *Hansa,* **87,** 1507 (1950); *J. Brit. Shipbuilding Res. Assoc.,* **6,** No. 2, 100 (1951).

Oil-based red lead paints are very satisfactory for rust protection, although lack of adhesion of top coats may be caused by unevaporated aromatic solvents. A quicker drying and hardening film is obtained by including chlorinated rubber in the formation. A more effective and economical finish consists of a metallic pigment in a special vehicle. This paint preserves mill scale and protects clean surfaces from electrolytic corrosion.—RPI.

5.4.5, 4.3.3

Water and Alkali Tests. Cleveland Paint and Varnish Production Club. *Paint, Oil, Chem. Rev.,* **113,** No. 24, 127-129 (1950); *Official Digest Federation Paint and Varnish Production Clubs,* No. 311, 1042-1047 (1950).

Data are reported on the effect of water and 3 percent sodium hydroxide solution on dried films .00125 ± .001 inch thick of the materials investigated by the Cincinnati Club.—RPI.

5.4.5, 4.3.6

Role of Protective Coatings in Search for Deep-Water Oil. *Paint Progress,* **8,** No. 2, 1-2 (1950).

A description of the measure taken by the use of protective coatings on oil plants to preserve them from the corrosive action of salt water.—RPI.

5.4.5, 2.2.5, 6.2.3

Anti-Corrosive Compositions. *Paint Manuf.,* **20,** 439-442 (1950) Dec.

The first report of Joint Technical Panel N/P2—Paints for Underwater Service on Steel of the British Iron and Steel Research Assoc., giving results of a test program evaluating 68 anti-corrosive paints for marine service, is summarized. Painted mild steel specimens were tested either by immersion in sea water from rafts or by the C.R.L. accelerated rotor test. The best composition had a pigmentation of 2 parts basic lead sulfate with 1 part each of aluminum powder, barytes and Burnt-island red, bound in a modified phenol-formaldehyde stand-oil/tung oil medium.

5.4.5, 8.9.5

Lining Ships' Tanks. H. W. RUDD. *Australian Plastics,* **6,** No. 59, 18+ (1950).

The problem of the protection of ships' cargo tanks, especially in oil tankers, is considered. Protectives based on vinyl and vinylidene plastics, polysulphide resins, and other rubber-like polymers have been tried. Research has shown the superiority of polyvinyl butyral coating in resistance to penetration by water. On the basis of this, a system has been built up with a lightly pigmented polyvinyl butyral primer followed by two further coats based on polyvinyl chloride/acetate copolymers.—RPI.

5.4.5, 6.4.2, 8.1.2

Painting Aluminum Parts for Window and Door Awnings. W. RUDOLPH. *Ind. Finishing,* **26,** No. 8, 24-26+ (1950).

Details of the plant are given. The aluminum parts are loaded in a wide mesh stainless steel basket, degreased in hot alkali solution, dipped in a corrosion-proofing solution, rinsed in chromic acid, dried and given one coat of enamel which is stoved by infra-red.—RPI.

5.4.5, 1.3

Coatings Research at Batelle Memorial Institute. E. R. MUELLER AND B. G. BRAND. *Paint Varnish Production Mgr.,* **30,** 10-12, 20-21 (1950) Sept.

General organization and procedure for handling research at Battelle. Facilities for coatings research and typical projects. Batelle's North Florida Research Station for study of marine fouling, corrosion, deterioration, etc. 12 references. —MR.

5.4.5, 8.9.5

Chlorinated Rubber for Ships' Paints. H. A. W. NIJVELD. *Rubber,* **6,** 50-51 (1950).

Paints made with chlorinated rubber as binder are noted for their resistance to chemicals, damp and wear and for good adhesion. In an underwater durability test, phenolic resin and chlorinated rubber media gave the best results.—RPI.

5.4.5, 6.4.2

New Finish for the Decoration and Protection of Aluminum. JOHN M. PER-

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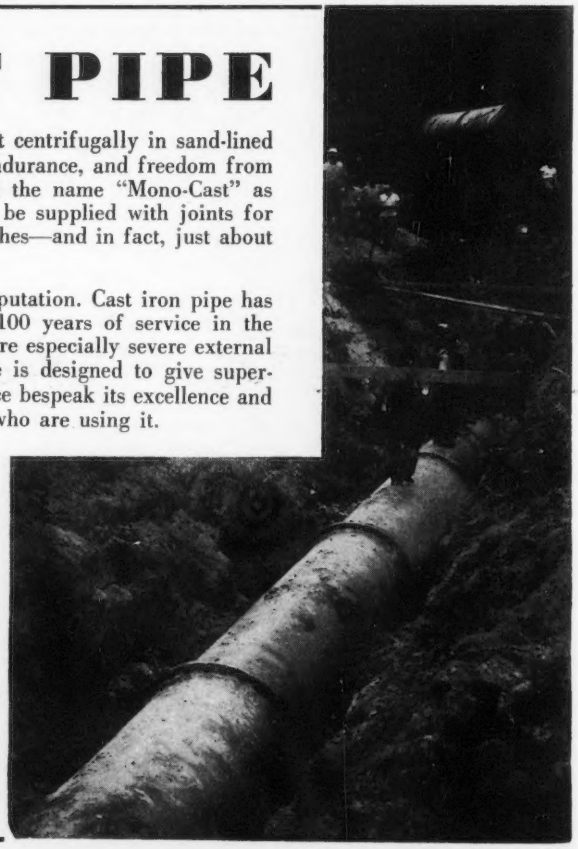

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FECT. *Light Metals* (England), **13,** 235-239 (1950) May.

Advantages of finish developed by Alumilite and Alzak, Ltd., in Britain, and known as "Enamel Plating."—MR.

5.4.5, 1.3, 6.6.11

Finishes for Wood. ROBERT E. PRINCE. *Paint, Oil Chem. Rev.,* **114,** p. 12+ (1951) May 10.

Reviews the above, giving typical formulations of the various types.—BLR.

5.4.5, 1.6

Paint Film Defects—their Causes and Cure. M. HESS. Chapman & Hall Ltd., London, 1951, xvii+ 544 pp. Price 50/.

This book, a revised and enlarged translation of the author's German work on the subject, is undoubtedly an acquisition to the British paint industry. The author has compiled a very comprehensive list of faults which can occur during storage, application or service, and in each case has discussed the causes of failure and possible remedies. The result is a comprehensive book containing a wealth of information which becomes readily accessible to the reader through a well-planned index and numerous cross-references. In addition to the conventional paints, the author has included the newer industrial finishes and modern methods of application. It is not difficult to foresee that this book will become a standard reference work on paint failures.—RPI.

5.4.5, 4.1

Neoprene as a Maintenance Coating. *Materials & Methods,* **33,** 102 (1951) Feb.

Designed as a maintenance coating for steel, wood and cement, the new Neoprene coating manufactured by Gates Engineering Co., is said to possess all the temperature, abrasion, fume, acid and oil resistance properties of Neoprene.

5.4.5, 4.3.3

Alkali Attack on Paint. G. W. MACK. *Paint Manuf.,* **21,** 121-125, 144 (1951) Apr.

Discusses optimum practice in painting alkaline surfaces such as concrete and plaster. Mechanism of attack is considered. Use of pretreatments with inorganic salts is reviewed.—BLR.

5.4.5, 5.4.8

Protective Coatings. *Machine Design,* **23,** No. 4, 225 (1951) April.

Tinallium, a nondrying black paste, used for heavy-duty corrosion and rust control on all metals, woods and concrete mixes. This paste can be applied with brush while cold regardless of climate conditions; resists acids, salts, air, noxious fumes; is nonabrasive; and acts as lubricant on interior parts. The protective coating can be used for exposed mechanisms, armatures, axles and bearings, automobile springs, underground or underwater piping systems.—INCO.

5.4.5, 6.2.2, 6.3.19, 6.4.1

Experiences With Painting Iron, Zinc, and Light Metals. (In German.) G. HOFFMANN. *Metalloberflache,* ser. B, 3, 69-71 (1951) May.

Discusses preparation of the metal surfaces, application and drying of different types of base coats and protetcive paints, and determination of the weathering resistance of paints, varnishes, or lacquers. Because of the danger of galvanic action, the importance of insulating different metals against each other is indicated.—BLR.

5.4.5, 6.4.2

Recent Developments in Aluminum Pigments. Parts I and II. S. E. JACK. *Can. Paint & Varnish Mag.* (Canada.) **25,** Nos. 2 and 3, 18-20+, 42-44+ (1951) Feb., Mar.

Aluminum-paste pigments have been available in Canada for a number of years under the designations of Alpaste 100 (or Standard Alpaste) and Alpaste 200 (or Extra Fine Lining Alpaste). Recently two new types of aluminum-paste pigments—the polished and the non-leafing types—have become available. Polished Alpaste is marketed as Alpaste 120 (standard) and Alpaste 220 (extra fine lining). A recently developed process makes it possible to supply aluminum-paste pigments with 50 to 200 percent increase in specular reflectance in leafed out paint films. The individual flakes of the polished type pigments are more planar than those of the regular products, and when in a leafed out film a smoother finish and increased specular reflection are obtained which give an overall effect of high metallic lustre. The increased specular reflectance is gained at the expense of diffuse reflectance and the surface will appear lighter or darker than one produced from the older type of pigment. Polished pigments have a tendency to accentuate surface imperfections, but this can be avoided by thorough dispersion, clean vehicles, clean surfaces, and cleanliness in application. The leafing power and leaf stability of polished pastes are in every way comparable to those of the unpolished grades, but a greater loss of leafing power can occur in an unpolished paint than in a

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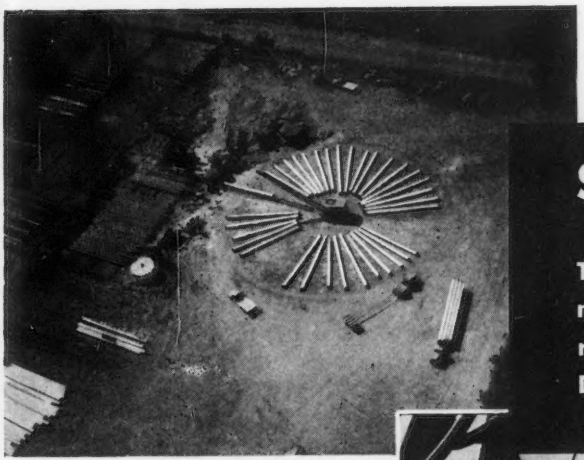

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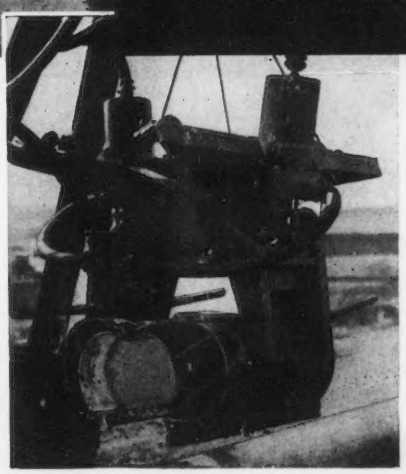

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polished paint without it becoming apparent in application. Vehicles of good levelling properties are essential since brush marks are highlighted by the smoothness. Polished aluminum pastes are marketed with about 73 percent non-volatile content as compared with 65 percent for the unpolished grades. The main advantage of the use of polished aluminum-paste pigments is that they enable paint manufacturers to produce novel aluminum paint finishes.

Non-leafing aluminum pigments have been developed for use in polychromatic and other textured finishes. A small quantity of aluminum flake lying within and more or less parallel to the surface of the coating film reflects lights from various depths and at various angles. Innumerable variations of effects can be produced depending upon fineness and concentration of the aluminum flake, application methods, drying methods and many other variables. Non-leafing aluminum-paste pigments are marketed as Alpaste 1100 and Alpaste 1200 with 70 percent non-volatile content. Besides use in metallics, the non-leafing pastes have potential applications in primers for wood, for intermediate barrier paints for structural metal, and whether the moisture impedence and protective properties of aluminum paint can be employed to advantage, but where the aluminum color is not desired and a final color coat is used.—ALL.

5.4.5, 6.4.4

HAE Revolutionary New Coating for Magnesium. Magazine of Magnesium (U.S.A.) **1951,** 1-3, May.

A new finish for magnesium and magnesium alloys, known as HAE, has been discovered at Frankford Arsenal during investigations to determine performance limits of various magnesium coatings for Ordnance applications. The outstanding characteristics of HAE are its excellent corrosion resistance, high melting point, good dielectric strength, and hardness. It is normally brown in color, and is an excellent paint base. HAE is applied electrolytically in much the same way as aluminum alloys are anodized, and can be applied to any of the commercial magnesium alloys, wrought or cast. Extensive tests have been conducted to determine the durability of the coating. The coating is approximately 0.001 to 0.0015 in. thick, depending on the length of time of treatment. A coating 0.001 in. thick will resist an electrical potential of 550 volts at 60 cycle. After 5 hours exposure to salt spray, the HAE-treated panels showed no signs of corrosion, while the dichromate-treated panels were badly corroded. Abrasion tests, using the Taber Abraser with CS17 wheel and the 1000 gram weight, produced no breakdown of the HAE coating after 8000 cycles. It is expected the applications of magnesium will increase as a result of the use of the new coating in (1) assemblies involving the use of magnesium in direct contact with other metals, (2) marine applications, (3) high temperature applications, (4) uses where extremely high hardness and abrasion resistance is required, (5) applications where chemical inertness to most materials is required, and (6) where good corrosion resistance is required without the necessity of depending on the application of organic and mineral coatings. At present, HAE is available for military applications only. An article on the same material was also published in Modern Metals, **7,** No. 4, 36 (1951) May.

5.4.7, 5.4.5, 7.2

Continuous Dip System Improves Tar Coatings. F. R. Adams and G. E. Loftin. *Iron Age,* **168,** 92-94 (1951) Aug. 2.

A continuous dipping system using a heated tar bath for cast-iron soil pipe and fittings which gives a coating superior to that produced where pipes are heated and then dipped. This bath is held at 300° F and just enough residual heat for quick drying is retained.—MR.

5.4.8, 2.2.5, 2.3.2, 1.7.1

Results on Testing Surface Waterproofings. F. O. Anderegg. *Amer. Soc. Testing Mat. Bull.,* No. 171, 48-53 (1951).

An account of field and laboratory tests on various kinds of sealing materials for brick and cement, including conventional paints, synthetic resin emulsions and silicones. Silicone treatments proved effective in repelling water. The presence of efflorescent salt crystals is the most potent cause of surface breakdown.—RPI.

5.7 Treatment of Medium

5.7.4, 2.3.9

Radioactive Tracer Method for Evaluating Water Displacing Compounds. Stanley L. Eisler, U. S. Arsenal, Rock Island, Ill. Report 50-2557; Project TB5-6010A, Report 13, October 1950.

A radiometric method for evaluating water-displacing compounds has been developed that is far more selective than the present U. S. Army test method AXS-1759. It is recommended as a valuable supplementary test wherever the nec-

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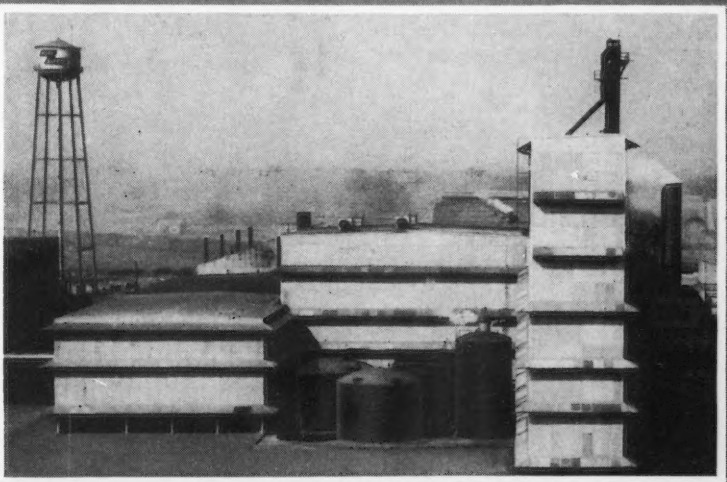

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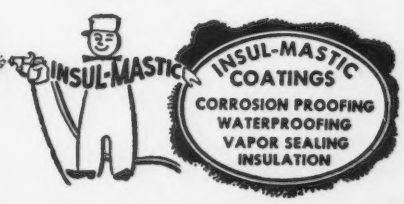

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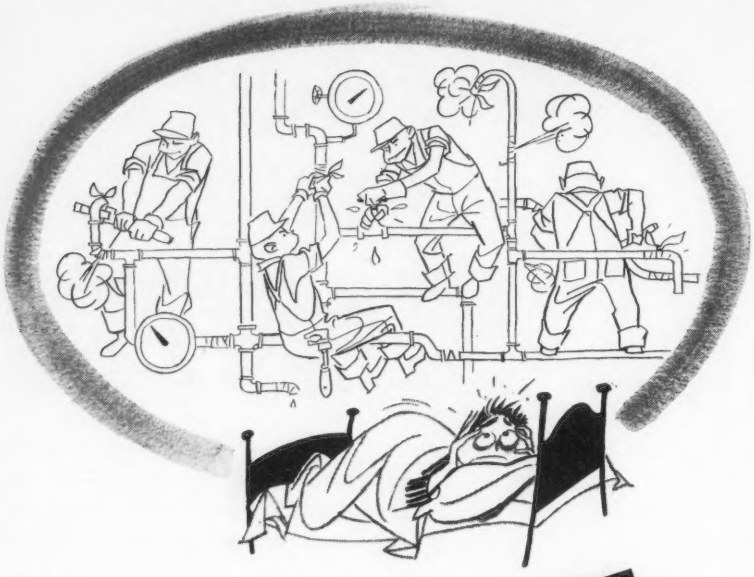

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The procedure consists of momentarily dipping a clean, sandblasted, 2- by 3- by 0.0625-in. steel panel in a beaker of water containing about 0.5 microcurie sodium sulfate S-35 per milliliter, draining it vertically for 5 seconds in contact with absorbent paper, immersing it horizontally for 15 seconds in a Petri dish containing 50 ml of the test solution, hanging it in trichloroethylene vapor degreaser for 15 minutes, desiccating it until cool and counting it in a specified manner using a suitable counter tube and scaling unit. A compound is considered to pass the radiometric test if the net counting rate is less than 25 percent that of a nondisplacing paraffin oil control.

Of fourteen commercial water-displacing compounds judged by the unmodified AXS-1759 method, four failed, six passed, and four were borderline cases. Using the radiometric method, five of the fourteen compounds passed, two of these in a superior manner, and eight failed. One compound would also have been rated satisfactory, in agreement with the unmodified test, had it been completely removed by the vapor degreasing treatment.

None of the compounds tested restored the counting rate to the normal background value, indicating that none effected complete water displacement. This may not be required, however, since rust preventive coatings prevent corrosion by any residual water sufficiently long to meet specification requirements. These tests also showed no appreciable residual count attributable to adsorption of the tracer on the steel surface. Thus the method permits rating the efficiency of water displacers without the results being obscured by various stains, drainage marks, questionable surface film and other visual signs that could not previously be ascribed to either residual water or additive action.

5.7.8

Change in Corrosion Behavior Caused by Wetting Agents. (In German.) LUIGI PIATTI. *Chimia* (Switz.), **5**, 8-11 (1951) Jan. 15.

Experiments on the corrosion effect of plain tap water and of tap water plus 4 percent wetting agent on plain-carbon-steel plates show that the wetting agent prevents pitting and results in more uniform corrosion. Photographs and micrographs illustrate the results. Data are charted and tabulated.—BLR.

5.8 Inhibitors and Passivators

5.8.2, 4.6.12, 8.4.3

Special Compound Proves Effective Water Conditioner. F. LATTER AND C. PARKE. Pur-O-San Co. *Oil Gas J.*, **49**, No. 44, 72-74, 77 (1951) Mar. 8.

Results of test of a mixture of quaternary ammonium salt, a condensed ethylene oxide-fatty acid wetting agent and sodium nitride (Pur-O-San) as a corrosion inhibitor in the secondary recovery of oil by water flooding. The use of the amine type inhibitor reduced the cost of corrosion repair. Bacteria tests indicated a 95% kill on this water in 24 hours after treatment with 10 p.p.m. Injection rate tests on 6 wells showed an average increase of approximately 33%. 7 references.—INCO.

5.8.2, 5.9.2

Pickling Agent Displays High Inhib-

iting Action. *Product Eng.*, **22,** No. 2, 190, 192 (1951) Feb.

This inhibitor is supplied as a clear almost odorless liquid that is added to acid solutions in the concentrations range from 0.1-0.3% of the volume of the acid mixture. Its inhibiting action in hydrochloric acid and sulfuric acid from room temperature to 150°F is of the order of 95-99% depending upon temperature. In phosphoric acid the inhibiting action is above 90% and is of a high order of magnitude even at the boiling point of dilute acid mixtures. It should not be used with sulfamic acid. Its inhibiting action with hydrofluoric acid is 75%. With fluoboric acid the inhibiting action is 50%. This inhibitor lowers the surface tension of acid solutions causing a light foam to form that will trap fumes. The actual drag-out of acid on the work being pickled is reduced because of the smaller pendent drops formed. Tests made with steel sheet indicate a lowering of drag-out of 10-15%. All tests made with this inhibitor added to various acid solutions indicated that the hydrogen embrittlement is either not changed over that experienced with bare acid or the embrittlement is reduced. It can be easily removed from metal surfaces by means of an alkali cleaner. Mfd. by Enthrone Inc.—INCO.

5.8.3

Relationship Between Variation of Surface Tension of Wetting Agents With Time and Their Wetting Rates. (In German.) H. LANGE. *Kolloid-Z.*, **121,** 130-134 (1951) Mar.

Reports recent experimental and theoretical studies on the relation between surface tension and wetting efficiency and on surface tension as a function of time and concentration. Data are tabulated and charted.—BLR.

5.8.3, 5.4.1

The Pigment/Vehicle Relationship in Anticorrosive Paints. J. E. O. MAYNE. *Paint Technology*, **16,** No. 187, 297-298 (1951) July.

A summary of a paper presented at the Oil and Colour Chemists' Association conference at Scarborough, 1951. It reviews present knowledge on the inhibition of corrosion of iron and steel by means of paint. Three types of pigment are discussed, viz: inert, basic and soluble pigments. The basic pigments are effective corrosion inhibitors because they form soaps, such as zinc linoleate, which render water non-corrosive. Zinc chromate and zinc tetrahydroxychromate are important soluble pigments which inhibit corrosion, probably owing to the effect of the soluble chromate ions.—ZDA.

5.8.3, 7.2

The Role of Sodium Silicate in Inhibiting Corrosion by Film Formation on Water Piping. LEO LEHRMAN AND HENRY L. SHULDENER. *J. Am. Water Works Assoc.*, **43,** 175-188 (1951) Mar.

Solutions of different sodium silicates in very low concentration (12-1400 ppm. silica) are shown to achieve an equilibrium between ionic and colloidal silica. Silica is not removed from these solutions by metals until the solid corrosion products of metals form. The siliceous film which inhibits the corrosion process was identified by chemical analysis, microscopic examination, and X-ray diffraction analysis. Describes the film formed by the adsorption compound in galvanized iron and brass piping during service. 11 references.—BLR.

6. MATERIALS OF CONSTRUCTION

6.4 Non-Ferrous Metals and Alloys—Light

6.4.2, 8.9.3

Aluminum Pipe Line in Use for Seventeen Months Shows no Corrosion. *Am. Metal Market*, **58,** No. 126, 9 (1951) July 3.

Recent uncovering of a 40-foot bare aluminum bypass installed seventeen months ago in an Alabama-Tennessee Natural Gas Company's 8-inch aluminum pipeline revealed no discoloration or corrosion of any sort, either on the outside where bare pipe was in contact with soil, or on the inside which carried natural gas. The test was supervised by officials of the company and representatives of Reynolds Metals Company.—ALL.

6.4.2, 5.9.2, 5.9.4

Chemical Surface Treatment Extends the Durability of Koolvent All-Weather Aluminum Awnings. N. P. GENTIEU. *Products Finishing* (U. S. A.), **15,** No. 7, 38-43 (1951) Apr.

Koolvent aluminum awnings, manufactured by the Koolvent Metal Awning Corp., are being permanently installed as an integral part of houses or commercial buildings. They provide air-conditioned shade in the summer and all-weather protection all year. The awnings consist of a series of alternating separate layers of aluminum strips formed with their edges at right angles. Place is provided between overlaps for the free circulation of air and the admission of light. The awnings are treated with a paint finish system to insulate the metal from the weather, protect it from atmospheric contaminants and decorated to suit individual tastes. Good results have been obtained from tests made with a weatherometer and also under atmospheric conditions. The Cook Paint and Varnish Co. developed rugged enamels from non-fading pigments and durable liquids, that meet the unusually rigid requirements of a constantly exposed surface. The awnings are pretreated with the chemical coating Alodine at the paint-metal interface, which anchors the decorative finish securely to the aluminum. Comparative tests involving both Alodized aluminum panels and acid-cleaned aluminum panels in salt spray, humidity and water (total immersion soaking) provided the Alodine provides high protection to both metal and paint finish. The Alodizing installation at the Koolvent plant is described and illustrated. This is composed of five tanks for the following stages: "Ridolin" No. 3192 alkali-solvent cleaner, fresh water rinse, Alodizing with Alodine, fresh water rinse, "Deoxylyte"—acidulated water rinse.—ALL.

8. INDUSTRIES

8.8 Group 8

8.8.1, 5.4.2

A New Plant for the Separation of Fatty Acids. *Intern. Chem. Eng. Process Ind.*, **32,** No. 2, 73-75 (1951) Feb.

The plant at Bromborough Pool represents the realization on a commercial scale of the "Emersol" process developed by Emery Industries, Inc. of Cincinnati for the separation of liquid and solid acids. This process depends on the relative insolubility of solid acids and solublity of liquid acids in methanol at a sutably low temperature. The separation of stearine and oleine is described in successive steps and is shown in simplified form in a pictorial flow diagram. All parts in contact with fatty acids are of stainless steel or aluminum. The solvent plant, designed and erected by the Blaw-Knox Construction Co. U. S. A. is described including the crystallizer, vacuum filter, stills, control room and the safety precautions taken.—INCO.

8.8.1, 7.6.8

Furfural Corrosion in Extractive Distillation Equipment. F. R. JELINEK.

Gives you a quick, easy method of determining what metal alloys to use in connection with 143 different corrosive agents. Ideal for metallurgists, product designers, engineers, chemists, purchasing agents. Sized to fit your pocket. Developed by The H. M. Harper Co., America's leading specialist in non-ferrous and stainless fastenings.

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Neches Butane Products Co. Paper, N. A. C. E. Meeting, Orange, Texas, Feb. 23, 1950. *Corrosion*, **6**, No. 6, 12 (News Section) (1950) June.

Elimination of costly corrosion and equipment fouling troubles in fractionation equipment for separating close boiling C_4 hydrocarbons by extractive distillation with furfural at the Neches Butane Products Co.'s butadiene plant resulted from the addition to the furfural streams of triethanolamine. This neutralized acids formed from the furfural and reduced polymer formation.

8.9 Group 9

8.9.1, 6.4.2, 8.10.4, 7.1

Prevention of Corrosion in Naval Aircraft. Parts I & II. N. E. Promisel and G. S. Mustin, Airborne Equipment Division, Bureau of Aeronautics, Department of the Navy, Washington, D. C. Paper presented at the Seventh Annual Conference and Exhibition, Natl. Assoc. Corrosion Engrs., New York, N. Y., March 13-16, 1951. *Corrosion*, **7**, Nos. 10 and 11, 339-352 and 377-389 (1951) Oct., Nov.

Part I. Corrosion prevention of aircraft starts with proper design, proper selection of materials and control of fabrication processes. Free drainage, avoidance of dissimilar metal contacts, electrochemical insulation, proper heat treatment and cleanliness are stressed. Water contact, essential to common corrosion, is prevented or de-activated by chemical surface treatments, plating, organic coatings, preservative compounds, dehydration, hermetic sealing or other waterproofing techniques. Sacrificial protection, where advantageous, is provided

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CORROSION can't be stopped by ordinary paints or conventional protective coatings. They can't protect surfaces against the ravages of rust for any appreciable length of time.

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Bitumastic Coatings stop corrosion caused by moisture—acid fumes—alkaline fumes—corrosive soil—salt air—heat.

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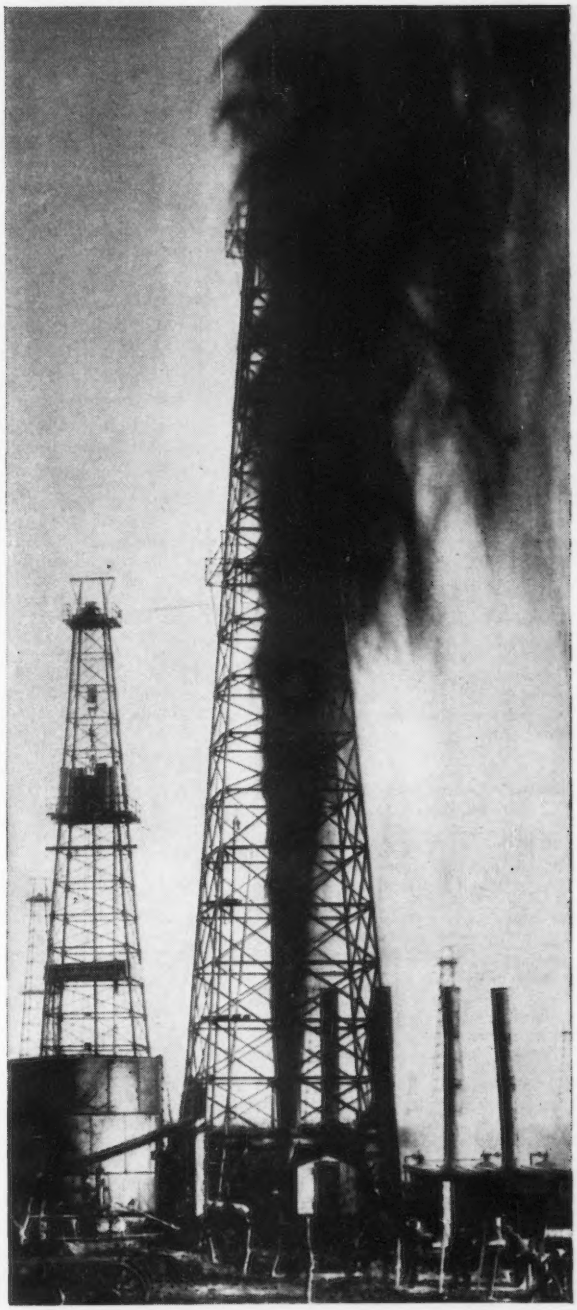
There are 6 Koppers Coatings—formulated to control corrosion of metal and deterioration of concrete. Use the coupon for full information.



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by cladding, plated surfaces and readily replaceable parts such as washers.

Special consideration is given to stress corrosion cracking, thin magnesium alloy sheets, engine cylinders and other internal engine parts, compressor housings, propeller shafts and other operating mechanisms where routine treatment is not practicable. Use of cadmium-tin plating, porous chromium plating, nickel plating, phenolic resin coating and phosphate treatments have given good results in these special applications. Exhaust stack failures and compressor blading failures from intergranular corrosion have occurred. Equipment normally corrosion free when operative needs additional protection during idleness. Frequent inspection of the airplane for corrosion and such preventive maintenance features as water washing seaplanes, tuch up of worn or abraded paint surfaces. The use of plating in the repair of damaged parts is common. Manganese is promising as a cadmium substitute and diffused silicon and aluminum coatings show promise of making molybdenum oxidation-resisting. Titanium and its alloys may solve some present difficulties.

Part II. Types of preservation systems used on engines are listed and described. Tables give partial breakdown of reciprocating engine preservatives and on gas turbine engine preservatives. Specific types of corrosion encountered are described and remedial methods discussed. Corrosion problems with high temperature materials, ordnance, electronic instruments, idle aircraft, spare parts are listed. Specific procedures of airplane maintenance are discussed.

8.9.1, 7.1, 3.5.9

High-Temperature Problems in Aircraft Jet Engines and Turbo-Superchargers. R. B. JOHNSON. *Metal Progress*, **59**, 503-510 (1951) Apr.

Presents a metallurgist's viewpoint of some of the problems encountered in high-temperature metals during development of aircraft jet engines and turbo-superchargers. Parts discussed are the combustion-chamber liner, the nozzle diaphragm partition, the turbine buckets; and the tail cone on the jet engine; and the nozzle box, the nozzle diaphragm, the turbine wheel, and turbine buckets on the turbo-supercharger. All designs and parts referred to are obsolete, but exhibit typical problems in materials of construction. Physical and mechanical properties of various metals and alloys used are tabulated and charted; defective pieces are illustrated.—BLR.

8.9.3, 6.4.2, 7.2

Lightweight Pipelines: Aluminum Has Come of Age. W. B. MOORE. *The Oil Forum* (U.S.A.), **5**, No. 2, 47-48 (1951) Feb.

Nine installations with a total of 61,420 ft. of aluminum pipelines have been constructed since 1947 for petroleum industry use. The pipes range in size from 4-in. to 10¾-in. OD. The lighter weight of aluminum pipe in comparison with steel pipe of the same OD, makes its cheaper to string as the truck or low-boy can carry three times as many lengths; the number of round trips is reduced, with consequent savings in gas and time. Two unloaders can easily handle 40-ft. lengths of 8½-in. OD aluminum pipe (weight, 320 lbs.) at a faster rate than would be possible with the 950-lb. length of steel pipe of same size. Aluminum is easier to bend than steel, and thus requires less heavy bending equipment. Aluminum pipe is also more flexible since its modulus of elasticity is approximately one-third that of steel. Welding costs are decreased since it can be done with a single pass, requires no tacking and can be easily lined up. The operation of an aluminum pipe system involves decreased pumping cost due to lower coefficient of friction than that of steel pipe. Installations include an aerial river crossing with a lightweight cable suspension over the North Canadian fork of the Little Colorado River in Oklahoma. This installation has a pier-to-pier span of 318 ft. consisting of 11 joints of 10¾-in. OD, Reynolds Metals Co. 63S-T5 extruded pipe with 3/16-in. wall, 30 ft. in length, with ends bevelled at 30° for welding. A five-mile section of 6⅝-in. OD pipe was laid in one string in the sour crude oil fields of Arkansas.—ALL.

8.9.4, 1.2.2

Corrosion Problems of the Railroads. L. S. CRANE. Paper, Second Railroad Corrosion Conference at Wrightsville Beach, N. C., May 1-3, 1951, under sponsorship of The International Nickel Co., Inc. *Railroad Corrosion News Letter*, Vol. 1., No. 1 (1952) Jan. *Corrosion*, **8**, No. 4, 149-151 (1952) Apr.

Corrosion losses to American railroads are estimated at $268,000,000 annually. Major corrosion problems of railroads and remedies are listed including bridge painting, brine drippings damage, car painting, steam boiler corrosion cracking, Diesel engine corrosion difficulties with cylinder liners, bearing and injection systems, trackage losses from stress, humidity and mechanical deficiencies. Time to do certain kinds of corrosion preventive work is given, and the work of the American Railway Engineering Association in redesign of rail fillet area to give better stress distribution, is mentioned.

The above report was sponsored by National Association of Corrosion Engineers Technical Practices Committee 15 —Corrosion Control in the Transportation Industries.

8.9 Group 9

8.9.5, 5.4.5, 5.4.8

The Application of Marine Paints to Exterior Steel. R. MANSELL. *Org. Finishing*, **11**, No. 10, 15-18 (1950) Oct.

Properties and applications of marine paints, above and below water surfaces, and anti-fouling compositions are discussed. Attention is given to the U. S. Navy's plastic ship bottom paint which is superior to Moravian paint and eliminates the need for hot application methods and expensive mercuric oxide.

8.9.5, 6.4.2, 3.7.3, 5.3.4

Flying Fifteen. *Light Metals* (England, **14**, No. 155, 80-81 (1951) Feb.

Whittingham and Mitchel, Ltd., built a sailboat designed by Uffa Fox from light metal to specification Ba27, supplied by the British Aluminium Co. Ltd. The boat, called the "Flying Fifteen," has the following measurements: L.O.A., 20 ft.; L.W.L., 15 ft.; beam, 6 ft.; draught, 2 ft. 6 ins.; sail area, 150 sq. ft.; weight of hull only, 305 lb.; weight of keel, 380 lbs. The hull plating is butt-welded and all fluxes thoroughly removed; afterwards the weld was hammered to smooth the surface and to restore mechanical properties of the alloy. The iron keel is attached to the hull through very substantial frames with stainless-steel bolts. Finish consists of two coats of zinc chromate primer, followed by undercoat with a finishing coat of a durable synthetic enamel. The surface was subjected to a careful mechanical and chemical cleaning and a light etching treatment prior to the finishing treatments. Advantages of using aluminum in this construction include non-rusting and non-rotting properties, absence of any shrinkage due to exposure to sun, and impermeability to water which ensures maintenance of constant weight.—ALL.

WHAT KONTOL DOES

KONTOL DOES

Prevent corrosion—by forming a tightly adsorbed protective film on the metal surfaces of production equipment.

Prevent production interruptions—by eliminating the frequent break-downs and equipment failures caused by corrosion damage.

Save time—by being easy to use, by not complicating production procedures, by helping to keep the wells on production.

BOTH are important

WHAT KONTOL DOESN'T

KONTOL DOES NOT

Require elaborate application procedures—it can be pumped, lubricated or dumped into the well, or applied in solid stick form.

Require special safety measures—it is safe and convenient to use. No gloves, goggles, masks, or extraordinary precautions are required.

Complicate ordinary production procedures—it does not render emulsified crudes more difficult to demulsify. It does not deposit well-plugging precipitates.

A cheap corrosion preventive is not necessarily economical. Safety in handling, ease of application and the avoidance of treating difficulties or formation-plugging precipitates are all values to be carefully considered in selecting a corrosion inhibitor.

KB 52-2

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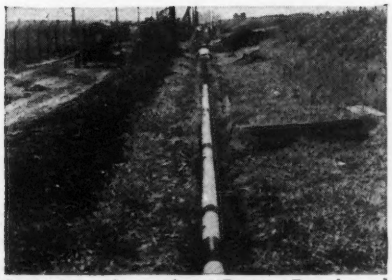
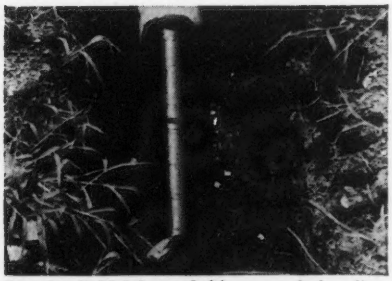
TRANTEX *polyvinyl* TAPE

. . . a cold applied wrap that protects underground and overhead oil and gas lines from corrosion



Tough, corrosion-resistant Trantex Tape is used here to repair holidays in the line. Easily applied, it is an economical material for this service.



For the field joints of this transmission line, Trantex Tape is used to give these critical spots lasting protection against corrosion.

FOR more than fifty years Johns-Manville has been manufacturing pipeline protection material. This experience, plus the knowledge gained in the research laboratory and in the field about the effects of corrosion, have gone into the making of "Trantex"—a new plastic tape for extending the service life of oil and gas lines.

Trantex needs no special equipment in its application. It is easily applied by hand or hand-operated devices. A pressure-sensitive adhesive forms a tight bond with the pipe—shields it against the general corrosive conditions that cause most pipeline failures. Trantex has proved remarkably resistant to the effects of soil chemicals, acids, alkalies, alcohols, oil and grease, sunlight and aging.

Check the basic properties of Trantex in the table below—each one is extremely important in the control of corrosion.

For more detailed information about Trantex *polyvinyl* Tape, write to Johns-Manville, Box 60, New York 16, N. Y.; in Canada, 199 Bay Street, Toronto 1, Ont.

	*V-10	**V-20
Dielectric Strength per mil thickness, Approx.	1,000 V	1,000 V
Insulation Resistance, greater than (ASTM-D-257-49)	100,000 megohms	100,000 megohms
Operating Temperature	200 F	200 F
Adhesion	30 oz per inch	20 oz per inch
Tensile Strength	30 lbs per inch	56 lbs per inch
Elongation at Break	250%	300%

"Trantex" is a black polyvinyl tape. It is available in two thicknesses—
*V-10 is a 10 mil tape for general conditions, and
**V-20 is a 20 mil thickness for use where a more rugged coating is specified.

JOHNS-MANVILLE JM PRODUCTS

Johns-Manville TRANTEX *polyvinyl* TAPE

PROTECTS PIPELINES AGAINST CORROSION

377

Isn't it logical?

First, Hill, Hubbell cleans the pipe to bare bright metal by Roto-Grit Blast. Then, temperature of pipe and coating and wrapping materials is precisely controlled at every step of the process.

Isn't it logical that factory-coated pipe should last longer? As a final precaution, every length of pipe protected by Hill, Hubbell is inspected with electronic holiday detectors before leaving the factory.

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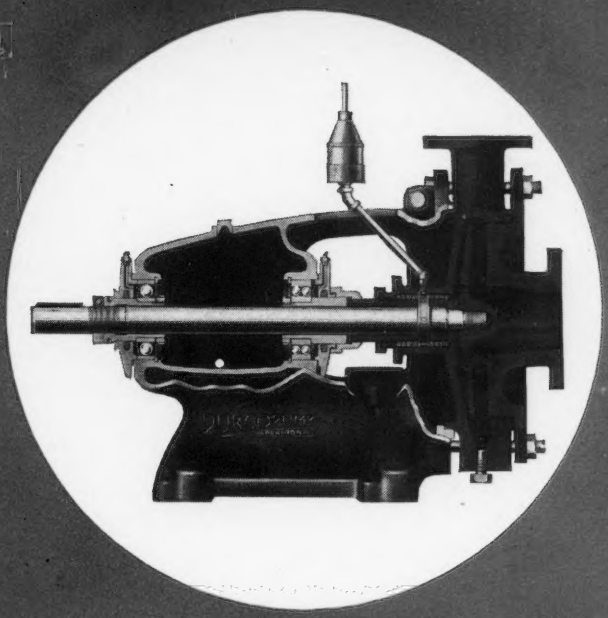

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THE NEW DURCOPUMPS PROVED IN ACTUAL SERVICE

THE SERIES R DURCOPUMPS

In actual service for more than a year, the Series R Durcopumps incorporate the best features of the earlier Series M Pumps with design changes which have improved performance and reduced maintenance.

Wet ends, of course, are interchangeable for meeting changing conditions. Among other improvements are a better stuffing box design, through-bored frame for positive alignment, and a more rugged impeller and heavier shaft for better balance and longer life. All features of the Series R Durcopumps are discussed in Bulletin P/1.

FOR OWNERS OF SERIES M DURCOPUMPS:
Many parts of the Series R Durcopumps are interchangeable with the Series M. It is possible for owners of these older pumps to convert to the Series R, thus taking advantage of design improvements. Write for Bulletin P/2 on Conversion.

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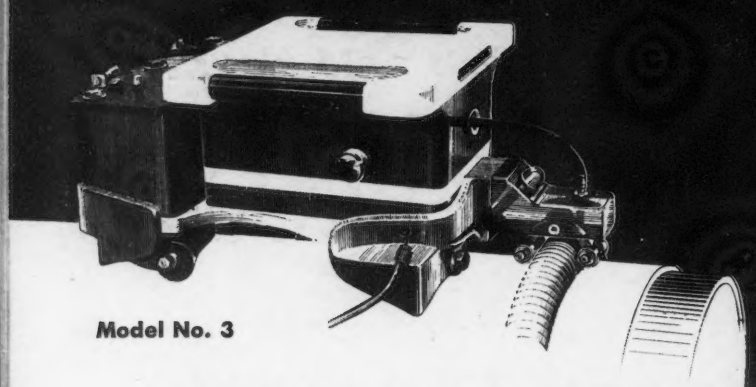
CORROSION RESISTING ALLOYS & EQUIPMENT

THE DURIRON COMPANY, INC.
Dayton, Ohio

The STEARNS ELECTRONIC HOLIDAY DETECTOR



Model No. 3

for making high voltage electrical inspection of pipe line coatings, above [illegible] as the unit is rolled along on the coated pipe by an operator. The complete Unit consists of the Generator coupled with an Alarm System, the Rolling Coiled Spring Exploring Electrode and Pusher Carriage Assembly. A small 6-volt storage battery serves as the power source.

THOROUGH INSPECTION

Fundamental precepts which are met by the Stearns Detector are:

(1) To generate a high voltage pulse of short duration regulated to hold the crest *intensity* within narrow limits irrespective of pipe size and the variable moisture conditions experienced during field inspection;

(2) To cause such a pulse to re-occur at a *rate* rapidly enough so as to have entirely traversed the coating surface with successive overlapping circumferential bands of ionization as the testing electrode is moved along the coated pipe;

(3) To *apply*, in a simple manner, these testing pulses to the coating by means of an exploring electrode embracing and self-conforming to the variable shape of the exterior of the coated pipe while being held in electrically effective contact with the coating surface at all times; and

(4) To give out audible and visual alarm signals as an instantaneous response actuated by the formation of a spark between electrode and pipe upon encountering a fault in the coating.

Under these principles the Stearns Detector in operation approaches the ideal in testing technique, with maximum safety to the operator, by providing thorough one-pass coverage while uniformly subjecting the coating only to the extent of electrical stress necessary to ensure complete inspection.

LIGHT WEIGHT

The Stearns Detector is fabricated from the lightest materials available having the required mechanical and electrical strength. The complete unit weighs 28 pounds — is 13.5" long, 9" wide, 7.5" high. A welded magnesium case for the Detector, and a wooden box for two 10-pound 6-volt batteries serve as sturdy containers for storage and shipping. The complete shipping weight, including an overnight battery charger, is 75 pounds.

SIMPLE TO OPERATE

The Stearns Detector can be operated without special training or experience on pipes of all sizes. The proper output voltage is set before shipment and the regulation is thereafter automatic — all functions of the Detector being controlled by a single 'On'-'Off' switch. The patented pulse generator, which makes possible such automatic voltage regulation, is an exclusive feature of the Stearns Detector.

DEPENDABLE SERVICE

The Stearns Detector has been developed through eleven years of field experience and continued research and has become the Standard of the Industry. All major parts of the high voltage generating circuit are custom built for their specific functions and fitted together into an electrical assembly of proved dependability. Users of Stearns Detectors are constantly ensured of receiving equipment in new condition as a result of the rigid shop and laboratory maintenance procedures followed by The D. E. Stearns Company.

*Patent Numbers Furnished Upon Request.

The D. E. STEARNS Company

SHREVEPORT. LOUISIANA, U. S. A. CABLE ADDRESS: DESCO

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